Factors Associated with Mathematical Ability in Young Deaf Children: Building Foundations, from Networks to Numbers

by

Karen L. Kritzer

B.A., Hofstra University, 1994

M.A., Gallaudet University, 1996

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This dissertation was presented

by

Karen L. Kritzer

It was defended on

December 15, 2006

and approved by

David Martin, Ph.D, Professor Emeritus, Gallaudet University

Ellice Forman, Ph.D, Department of Instruction and Learning

Louise Kaczmarek, Ph.D, Department of Instruction and Learning

Ellen Ansell, Ph.D, Department of Instruction and Learning

Dissertation Director: Claudia M. Pagliaro, Ph.D, Department of Instruction and Learning

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Karen L. Kritzer, Ph.D

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The study described in this document made use of quantitative and qualitative methodology to examine factors contributing to mathematical ability in young deaf children. Specifically, this study examined the relationship between relative level of mathematical ability and an understanding of basic concepts (i.e., color, letters, numbers/counting, sizes, comparisons, shapes, direction/position, self-social awareness, texture/material, quantity, time/sequence); and mediation techniques used by families (i.e., Feurstein's dimensions of Intentionality/Reciprocity, Transcendence, and Meaning).

Data were collected using: standardized tests (i.e., the Test of Early Mathematics Ability-3 and the Bracken Basic Concept Scale-Revised); structured early mathematics activities; and naturalistic observation. Based on scores from the Test of Early Mathematics Ability-3, sub-groups of participants who demonstrated relatively high and low levels of mathematical ability were selected to participate in a second level of the study. During this level, data were collected regarding the understanding of basic concepts by participants and mediation techniques used by the families, using a multiple case-study design.

Findings indicated that the following characteristics were associated with relatively high mathematical ability in young deaf children: early identification of hearing loss; at least one deaf parent; and fluent exposure to sign language in the home. Additionally children with relatively high mathematical ability were found to have a better understanding of basic concepts and to

come from homes in which higher quality mediation techniques were used. Homes of “more successful” children were language-rich and learning opportunities were readily available. Children with relatively low mathematical ability had less access to language within the home environment, and high-quality learning opportunities were limited.

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A Special Teacher…

Because of you I am richer…and I will always be grateful.

On my last day in the classroom as a deaf education teacher, this quote, printed on a magnet, was given to me by one of my students. Proudly, he explained that "richer" did not refer to money, but rather referred to my role as his teacher in making him "better" and "smarter." It is with the same kind of gratitude that I now wish to acknowledge all of the "teachers" who have contributed to making me "better" and "smarter" throughout the years leading up to this dissertation, not least of all, my former students who provided me with the impetus to begin this process.

First, I would like to acknowledge the children and schools who participated in this project. I am especially grateful to the families who welcomed me into their homes for a day. It is rare that researchers are allowed the "beyond the scenes" access to family life that I was granted during this project, and I am indebted to the families who made this important research possible.

Next, I want to thank the members of my dissertation committee for their time and valuable contributions to this project: Dr. David Martin, for sparking my interest in cognitive psychology back when I was a classroom teacher, and for everything he has taught me throughout the years I have known him; Dr. Ellen Ansell, for her valuable insights involving children's understanding of mathematical concepts; Dr. Louise Kaczmarek, for her thoughtful comments regarding young children, their families, and the nature of early development; and Dr. Ellice Forman, for her contributions in the area of research methodology.

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To all of the individuals described above, thank you for being my "teachers" and making my life richer. For you, I will always be grateful.

1.0 CHAPTER 1: INTRODUCTION TO THE STUDY

The study described in this document examines factors that contribute to mathematical ability in young deaf children. Specifically, this study examines the relationship between an understanding of basic concepts (i.e., color, letters, numbers/counting, sizes, comparisons, shapes, direction/position, self-social awareness, texture/material, quantity, time/sequence) and mathematical ability. In addition, this study explores the role that the family and informal learning plays in the development of a deaf child's comprehension of basic concepts and mathematical ability.

This chapter provides a general introduction to the study including: a description of the paradigm that guided the study, a discussion of the significance of the problem upon which this investigation is based, and the research questions used to guide the study.

1.1 PARADIGM

Given that the current study follows a mixed research design, the ontology for this study is also mixed. The first level of this study follows a postpositivist ontology. It is assumed that one reality exists to define "high mathematics ability" among young deaf children. The epistemological assumption of the first level of this study is that the screening test used to determine "high mathematics ability" was objectively administered and scored.

The second level of this study seeks to build off of and better understand the findings from the first level. An interpretive/constructivist paradigm is followed in the second level to define factors that contribute to success or "high mathematics ability" in young deaf and hard-of-hearing children. While multiple factors may contribute to high mathematics ability, the epistemological assumption of the second level of this study is that the researcher's own beliefs and values contributed to the factors that were examined.

1.2 STATEMENT OF THE PROBLEM

"Deaf people can do anything except hear" (Christiansen & Barnartt, 1995). This statement, made famous in 1988 by I. King Jordan, the first deaf president of Gallaudet University, has frequently been used to inspire members of the deaf community and deaf children alike. But how true is this assertion? Deaf students currently lag substantially behind their hearing peers in all academic areas (Moores, 2001). Low achievement is an obstacle that severely limits the potential of deaf children and makes the "anything" that they may want to do extraordinarily more difficult to accomplish.

The low achievement levels of deaf students in the area of mathematics have been well documented by multiple studies over a wide span of years and across national boundaries. Results from a mathematics achievement test given by Wood, Wood, Griffiths, and Howarth (1986) to 500 deaf children in England indicated that the deaf students, on average, lagged 3.4 years behind their hearing peers. In the United States, data from the Stanford Achievement Test, 9th edition indicate that by the end of high school, deaf/hard-of-hearing students achieve, on average, just a fifth grade level in mathematics computation and a sixth grade level in problem solving (Traxler, 2000). Deaf students also exhibit great difficulty in tasks involving reasoning (Allen, 1995). Even when non-standardized forms of assessment are used, deaf students perform significantly lower than hearing students (Luckner & McNeil, 1994; Marschark & Everhart, 1999).

Given the demands of the current information-age, and the performance requirements mandated by the national law "No Child Left Behind," (U.S. Department of Education, 2002) this low performance is not acceptable. Research in the field of deaf education must: 1) begin to examine the reasons why deaf students do not achieve on par with their hearing peers, particularly in the area of mathematics; 2) learn when this achievement gap begins, and 3) determine what can be done to reduce this disparity. This study addresses the first two of these needs and suggests strategies to address the third.

Research indicates that an understanding of formal mathematics skills and concepts is built upon a foundation of informal mathematical understanding (i.e., the mathematical ideas and concepts that are acquired outside of the school setting) (Ginsburg & Baroody, 2003). Young children construct this informal understanding even before they enter kindergarten (Ginsburg & Baroody, 2003). Furthermore, research findings indicate that early academic ability, particularly in the domain of mathematics, correlates with later achievement (Jimerson, Egeland, & Teo, 1999; Stevenson & Newman, 1986) and that early school experiences, family interaction and the home environment are important predictors of later academic success (Jimerson et al., 1999).

It is possible that the achievement gap for deaf students begins prior to school age. Hearing loss has a substantial impact on the learning experiences to which young deaf children have access. Deaf children do not benefit from the everyday auditory experiences that are taken for granted with hearing children (e.g., the spoken conversation going on around them, the cause-and-effect relationship of the telephone ringing before someone picks it up, or the sound of the door bell before the door is opened and a new person walks into the family home). Deaf children's already restricted opportunities for incidental learning are compounded when access to the language used in the home is restricted (Marschark, M., Lang, H.G. & Albertini, J.A., 2002). Only 27% of families with a deaf child report regular use of sign language (GRI, 2003). The majority of deaf children, therefore, are missing out on valuable learning opportunities at home that are relayed through use of a visual language. A late identification of hearing loss, which leads to delayed language acquisition, only contributes to this problem.

Due to the pervasive ramifications of hearing loss, and the number of learning opportunities that deaf children miss, it is possible that they do not enter school with the same understanding of basic concepts (i.e., color, letters, numbers/counting, sizes, comparisons, shapes, direction/position, self/social awareness, texture/material, quantity, time/sequence) or mathematical knowledge as their hearing peers. This could influence their learning of mathematical information and have a substantial impact on later academic performance.

1.3 PURPOSE OF THE STUDY

The purpose of this study was to identify characteristics associated with high mathematical ability and understanding of basic concepts in young deaf children. This study was guided by the research questions listed in the next section.

1.4 RESEARCH QUESTIONS

The following research questions guided this study:

What factors are associated with mathematics achievement in young deaf children?

a. What is the relationship between level of mathematics achievement in young deaf children and characteristics related to hearing loss (i.e., etiology of hearing loss, age of onset/identification, degree of hearing loss, use of assistive listening device)?
b. What is the relationship between level of mathematics achievement in young deaf children and characteristics related to parents (i.e., parents' hearing status, parents' level of education, participation in an early-intervention program, parents' signing skills)?
c. To what extent do young deaf children with varying levels of achievement in mathematics understand basic concepts such as color, letter, numbers/counting, sizes, comparisons, shapes, direction/position, self-social awareness, texture/material, quantity, and time/sequence?
d. To what extent do varying levels of achievement in mathematics in young deaf children correspond with effective use of mediation techniques (i.e., intentionality/reciprocity, transcendence, and meaning) in their families?

1.5 DEFINITION OF TERMS

Throughout this study, the following terms are defined as follows:

Basic Concepts: overall understanding of basic information in the areas of mathematics (i.e., number and operations, geometry and spatial sense, measurement, algebraic thinking, and problem solving), personal and social awareness, and early literacy (See Appendix C for further description and examples of each concept).

Mediation: the conscious transfer of information in a way that will make sense to the individual receiving the information.

Mediated Learning Experience (MLEs): a situation that includes at least one of the following characteristics:

Intentionality/Reciprocity (I&R): A conscious attempt made by a mediator to organize an environment or learning situation in a manner that will concretely maximize learning. Intentionality/Reciprocity describes the where and when, or the manner in which a learning experience is established. The critical element of Intentionality/Reciprocity is the environment established by the mediator.

Transcendence (T): The explanation offered by a mediator to provide a child with information that can go beyond, or transcend the immediate situation (Feuerstein, 1997). Transcendence describes the reason why a learning experience is needed. The critical element of Transcendence is the explanation offered by the mediator.

Meaning (M): The mediator encourages the child to use logical thinking to compare events and consider causal relationships. Meaning refers to how children apply their concepts or theories about the world to their observations (Ben-Hur, 1998). The critical element of Meaning is the questions asked by the mediator.

Networks: the schemata or mental systems of knowledge that individuals cognitively possess and use to explain their environment.

Numbers: overall mathematical ability; including processes such as classification, logical thinking, and problem solving.

Young deaf children: the population of children for this study; that is children with a profound hearing loss between the ages of 4 and 6 years who have not yet begun formal schooling (i.e., 1st grade).

1.6 CHAPTER SUMMARY

This chapter has presented the reader with an introduction to the research study described in this document including: a discussion of the problem framing the study, a description of the purpose of the study, the research questions, and a definition of terms that will be used throughout this document. The next chapter will provide an overview of the literature that forms the foundation upon which this study is based.

2.0 CHAPTER TWO: LITERATURE REVIEW

As discussed in chapter 1, it is known that deaf students attain low levels of achievement in mathematics. This low performance is evident in test scores (Traxler, 2000), as well as in tasks involving reasoning (Allen, 1995), logical thinking (Marschark & Everhart, 1999) and problem solving (Ansell & Pagliaro, 2006). However, little is known regarding when these low achievement levels begin or the basis for them. For this reason, it makes sense to examine the mathematics skills of young deaf children to determine if they are beginning formal schooling already at risk for low achievement.

2.1 THE "CURRICULUM" FOR EARLY LEARNING

According to the Principles and Standards for School Mathematics published by the National Council of Teachers of Mathematics (NCTM, 2000), young children in kindergarten are expected to engage in mathematics learning that incorporates content in the following areas: Number and Operations; Algebra; Geometry; Measurement; and Data Analysis and Probability. They will also be expected to engage in processes that incorporate problem solving, reasoning and proof, communication, making connections, and using representations.

In a joint position statement on "promoting good beginnings" written by NCTM in conjunction with the National Association for the Education of Young Children (NAEYC, 2002), it is recognized that early learning experiences play an important role in forming a foundation for future mathematics learning. The following recommendations are offered by the document. Young children should be encouraged to: use mathematics to make sense of the world around them; build upon their existing mathematical knowledge and experience; interact with mathematical ideas; and use mathematics during daily activities. It is also recognized in this position statement that, early in development, children's understanding of mathematics concepts may be intuitive rather than explicit in the following content areas: Number and Operations; Geometry and Spatial Sense; Measurement; Patterns and Algebra; and Displaying and Analyzing Data. As discussed in the position statement, lack of explicit awareness of these concepts may make it difficult for young children to make use of their prior knowledge and to make needed connections when encountering formal mathematics in school. Therefore, as discussed in the position statement, children between the ages of 3 and 6 years need to learn how to "mathematize" their environment, or learn to understand mathematically what intuitively makes sense to them (Joint Position Statement of the NAEYC and NCTM, 2002).

Since early learning experiences have lasting effects (Bowman, Donovan, & Burns, 2001), the informal mathematics knowledge with which young children arrive at school may impact their later learning of formal mathematics. One area in which young children possess early informal knowledge is in their understanding of numbers and quantity. Seminal research by Gelman and Gallistel (1992, 1978) indicates that children's early counting skills develop as verbal and written symbols are mapped onto preexisting, preverbal concepts of quantity. This prelinguistic, quantitative information possessed by infants and young children may be referred to as *protoquantitative* knowledge, or a *protoquantative schema* (Resnick, 1989). An example of a protoquantitative schema identified by Resnick (1989) is the awareness of change as an increase or decrease in quantity. Using this schema, even preschool age children can recognize that if they possess a certain quantity of something, and are given an additional quantity of the same thing, they will have more than they had before. If something is taken away, they will recognize that they have less. If nothing is added or removed, they recognize that the amount has not changed.

Young children's ability to map number words onto their understanding of quantity was examined in a study by Sarnecka and Gelman (2004). This study investigated young children's understanding of 'unmapped' number words, i.e., number words that they have not yet learned. In the first part of this study, children between the ages of approximately 3 and 4 years were found to understand that application of the number 'five' or 'six' would change if the quantity represented changed; however, they did not understand that the same number word must be applied to sets that are equal in quantity. Findings from the second part of the study indicated that children between the ages of 2 ½ years and 3 ½ years understood that when 'one more' is added to six, the quantity is no longer equivalent to six; however, if more is added to 'a lot' then there is still 'a lot.'

It is likely that these early quantitative schemas are responsible for the five counting principles that appear to be present in young children by the age of 3 years. According to Gelman and Gallistel (1992, 1978), the five counting principles present in toddlers are: *one-to-one correspondence*, *stable-order*, *cardinality*, *abstraction*, and *order-irrelevance*. These universal characteristics exist for any number system that is considered viable and may develop at very young ages.

The first three principles can be viewed collectively as they describe "how to count." *One-to-one correspondence* refers to tagging items so that each item receives one and only one tag.

These tags, however, do not necessarily correspond to traditional number words applied consecutively (Gelman & Gallistel, 1978). For example a child that is 2 ½ years old may be observed to count "two, six, ten" while counting three items. In this example, each item still receives one tag (Gelman, 1979). According to the *stable-order principle,* number words occur in a repeatable order. For example, the previously mentioned child may use "two, six, ten" again and again to count three items (Gelman, 1979). The *cardinal principle* says that the last number said when counting the items in a set represents the total number of items (Gelman, 1979). Using the above example, the child who counts "two, six, ten" would inaccurately use "ten" to refer to the quantity of three items included in the set.

The final two principles, *abstraction* and *order irrelevance*, describe how the three "how to count" principles are used. The *abstraction principle* refers to the idea that the "how to count" principles can be applied to anything to be counted (Gelman & Gallistel, 1978). For example, the items to be counted may be concrete, perceptually available items such as "apples", "people" and "animals", or abstract concepts such as "justice", "freedom", and "loyalty." The final principle is the *order-irrelevance principle.* According to this principle, items may be counted in any order. The final count will be the same regardless of the starting point (Gelman & Gallistel, 1978). For example, if one were to calculate the population of China, whether the count began with newborns or senior citizens, the final count would be the same.

In addition to number understanding, young children are also aware that quantity has a relationship with size and space. Young children's quantitative-spatial understanding was examined in a study conducted by Sophian (2002). In this study, the ability of 3 and 4 year old children to make judgments regarding the relationship between size and space was examined. The young children who participated in this study tended to confuse size and number, incorrectly predicting that more items would fit into a predefined space if the items were larger (i.e., more "big" things than "small" things would fit in "big" containers). With practice however, the children's understanding of the relationship between size and space became more conceptually accurate. This means that while the children in this study did not originally possess accurate knowledge of the relationship between size and space, they were quickly able to learn this concept with practice.

Young children's early mathematical knowledge is not confined to number. Preschoolers also demonstrate an early ability to categorize and recognize shapes. In a study by Deak, Ray, and Pick (2002), preschoolers' ability to classify and label objects by shape or function was examined. At the age of 3 years, children were capable of sorting objects by shape, while by the age of 4 years, children were able to classify by either shape or function. Young children's concept of shape was also examined in a study by Clements, Swaminathan, Hannibal, and Sarama (1999). In this study, the ability of 97 children between the ages of 3.5 and 6.9 years to distinguish shapes from other figures was examined. Children were found to function around Van Hiele levels 0 to 1 across all ages. At these levels, children name shapes based on their appearance (i.e., Van Hiele level 0) and are also capable of listing limited properties and attributes of the shapes (i.e., Van Hiele level 1). Children's accuracy in identifying circles and squares was considerably higher than their ability to identify triangles and rectangles. The authors suggest that the reasoning for this is that there are fewer prototypes for circles and squares than the other shapes; in other words, these shapes vary less in visual appearance, therefore they are easier to recognize. To a limited extent, the young children in this study were also able to describe properties or attributes of the shapes.

Young children also demonstrate an early ability to engage in the type of thinking required to solve story problems. A study by Sophian and McCorgray (1994) used two experiments to examine the development of 4-to-6-year-old children's understanding of part-whole relations. The first experiment examined the children's understanding of the part-whole relationship present in story-type problems, the focus being on problems in which the initial set was altered by adding or deleting items resulting in the final set. Five-and-six-year-old children showed a basic understanding of the problem as they responded with numbers that matched the structure of the problem (i.e., they offered a larger number for problems in which quantities were increased and a smaller number for problems in which the quantity decreased). Four-year-olds however always chose a smaller number regardless of the structure of the problem. The second experiment examined the children's understanding of part-whole relationships using a class-inclusion task. The purpose of this task was to examine if 4 year olds would demonstrate sensitivity to the part-whole relationship if numbers were not involved. Again, 5 and 6 year-olds showed understanding of the relationship, but 4 year olds did not. In both experiments, the superordinate group referred to the whole represented in the problem while basic-level referred to the part that was removed or added. When children were asked to compare the superordinate and basic-level groups, the older children consistently chose the superordinate group when asked to identify the set that had more. Older children also consistently chose the basic-level, or alternative set, when asked to label which group had fewer objects. Based on the findings from both experiments, the authors concluded that understanding of the relationship between superordinate sets and basic-level sets seems to develop between the ages of 4 and 5 years.

2.1.1 Deaf Children and Early Mathematics Knowledge

As indicated above, while a great deal is known about the early informal mathematics understanding of young children in general, less is known regarding the early mathematics skills of deaf children in the same age range. Only two studies were found regarding the mathematical performance of young deaf children; both examined the children's early number understanding. Zarfaty, Nunes and Bryant (2004) investigated the performance of young deaf and hearing children in spatial and temporal number tasks. Ten deaf and ten hearing children between the ages of 3 and 4 years participated in the Zarfaty et al. study (2004). All attended an educational program which utilized spoken language. Eight of the ten deaf children had cochlear implants. All of the children were presented with sets of objects both spatially (i.e., all items were presented together in a spatial array) and temporally (i.e., items were presented one at a time in a sequence). The children were tested for their ability to remember and reproduce the number of objects in the set with which they were presented. Results showed deaf and hearing children performing equally well on temporal tasks, however, the deaf children performed significantly better on the spatial task. These findings indicate that young deaf children's abilities to represent number are at least as well developed as their hearing peers before they enter school. However, the fact that the majority of the children participating in this study had cochlear implants could have played a critical role in the findings. These deaf children may be learning about numbers through an increase in auditory exposure to linguistic information.

Another study, conducted by Leybaert and Van Cutsem (2002), examined the development and use of counting by deaf children between the ages of 3 and 6 years. Twenty-one deaf children and twenty-eight hearing children, matched on school year, participated in this study. Three tasks were used. The first was an abstract counting task. This task required children to count as high as they could, stopping at 100. The second task was an object counting task. This task required children to count a series of animals or cartoon characters that were mounted on a wooden plaque. The third task required children to create sets of a given cardinality. While findings from this study indicate an age-related lag of approximately 2 years in deaf children's knowledge of the counting string as measured by the first task, the children who participated in this study did demonstrate age-appropriate skills in object counting and creating sets of a given cardinality. It is worth noting however, that although the majority of children who participated in this study (19 children out of 21) were exposed to manual communication at home, the sign system they were exposed to varied, with the majority being exposed to a sign system based on the spoken language of the country (French). In addition, 12 of the children also used cued speech at home along with speechreading. Similar to the children in the Zarfaty et al (2004) study, the children who participated in this study may have been learning about numbers through an increased exposure to spoken language.

Research is needed to specifically investigate the early mathematics knowledge of young deaf children with deaf parents. Deaf children with deaf parents are likely to be learning language using a visual-spatial, rather than an auditory-oral, natural language. This difference could influence the early informal knowledge of mathematics that these children bring to school with them.

2.1.2 Basic Concepts and Early Mathematics

Early learning in general, and early learning of mathematics concepts specifically, is rarely formally taught (Tudge & Doucet, 2004). Therefore, what young children know, or do not know, regarding early mathematics may be linked to their more general knowledge and experience, including the use of language and basic concepts.

While no study specifically stating that knowledge of basic concepts relates to early mathematics knowledge was found, research findings do indicate that basic concept knowledge is related to skills in other areas such as, general early academic achievement (Zucker & Riordan, 1990) and vocabulary development (Breen, 1985).

Findings from a study by Zucker and Riordan (1990) indicate that there is also a relationship between basic concept knowledge and early academic achievement. Seventy-five preschool age children were administered two measures designed to assess basic concept knowledge (the Boehm Test of Basic Concepts and the Bracken Basic Concept Scale). In a follow-up study one year later, the same children, now in kindergarten, were administered two achievement tests: the K-ABC Achievement Scale (a measure of generalized achievement) and the Metropolitan Readiness test (a test of reading readiness). The earlier administered basic concept measurement scales showed a strong correlation with the two achievement tests, suggesting that young children who demonstrate a strong understanding of basic concepts may be better able to demonstrate achievement in school.

Research findings also indicate that children's knowledge of basic concepts is linked to intelligence as measured by the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R) (Laughlin, 1995) and the Standford-Binet Intelligence Scale (Howell & Bracken, 1992). Eighty-three 4-year-old children participated in the study by Laughlin (1995) and 80 4-year-old-children participated in the Howell and Bracken study (1992). All children in the Laughlin (1995) study were administered the School Readiness Component of the Bracken Basic Concept Scale and the WPPSI-R. Children in the Howell and Bracken (1992) study were administered all components of the Bracken Basic Concept Scale, in addition to the Stanford-Binet Intelligence Scale. In both studies, a strong positive correlation was found between the intelligence test and the basic concept scale suggesting that children who demonstrate a strong understanding of basic concepts will also perform at a higher level on intelligence tests.

In addition, Breen (1985) investigated the relationship between children's scores on various school readiness tests, including two basic concept measurement scales (the Bracken Basic Concept Scale and the Boehm Test of Basic Concepts), and the Peabody Picture Vocabulary Test. Thirty 5-year-old children participated in this study, all of whom were enrolled in a half-day kindergarten program. A significant correlation was found between children's scores in the area of basic concepts and their score on the vocabulary test, suggesting that children who have developed a strong lexicon also demonstrate a stronger understanding of basic concepts.

While more research is needed to formally investigate the relationship between basic concepts knowledge and mathematics, the relationship between early mathematics knowledge and knowledge of basic concepts has been demonstrated in studies utilizing performance-based tasks. For example, the ability to solve mathematically-based story problems may be related to skills in other areas such as language or social skills. In a study by Jordan, Levine, and Huttenlocher (1995), the calculation abilities of kindergarten and first grade children with different types of cognitive functioning was examined. Children with low language levels were found to perform significantly worse than children with high language levels on story problems, yet they achieved comparable levels of performance on nonverbal and number-fact problems. In a study by Dobbs, Doctoroff, Fisher, and Arnold (2006), initiative, self-control, and attachment were all related to better mathematics skills, while behavior problems, withdrawal, social problems, and attention problems were related to weaker mathematics skills.

Since early mathematics is rarely formally taught, play behaviors may be an effective forum for observing young children's informal early mathematical thinking. Ginsurg, Inoue and Seo (1999) conducted a study in which 4-and-5-year-old children were observed in their preschool classrooms for a total of 469 minutes during free-play situations. Mathematical activities were found to comprise 209 minutes (44.6%) of the children's time. The children were observed partaking in activities related to five different types of mathematical awareness: patterns and shapes (36%), exploration of change (22%), relations (18%), classification (13%), and enumeration (11%). A precursor to emerging mathematics skills such as those demonstrated in the Ginsburg et al. (1999) study could be the language, objects and activities children use symbolically during free-play situations. Research by Huttenlocher, Jordan, and Levine (1994) suggests that the ability to engage in symbolic play emerges at approximately the same time as the ability to use physical models or manipulatives. Children's use of these physical models during play supports their early problem solving prior to their being able to calculate verbal mathematics problems.

2.1.3 Deaf Children's Understanding of Basic Concepts

Research related to deaf children's understanding of basic concepts is limited. While hearing children who experience difficulty learning have also demonstrated difficulty with basic concepts (Bracken, 1998; Kavale, 1982; Nelson & Cummings, 1981; Spector, 1979), only one study was found specifically related to deaf children. Findings from the study by Bracken and Cato (1986) indicate that deaf children experience delays in basic concept development. In the

Bracken and Cato (1986) study, the scores of a group of 17 deaf children and 17 hearing children, all of whom were approximately 6 years of age, matched for gender and race, were compared for their understanding of basic concepts (i.e., color, letter identification, numbers/counting, comparisons, shapes, direction/position, social/emotional, size, texture/material, quantity, time/sequence) as measured by the Bracken Basic Concept Scale (BBCS). Results showed that the deaf children performed conceptually at a level equivalent to mental retardation on all subtests. These scores were approximately 2 standard deviations below their hearing peers across all basic concepts measured by the test. While the deaf children received the highest score in the "School Readiness Composite" (i.e., the first five concepts measured by the test: color, letters, numbers/counting, comparisons, shapes), their scores were not significantly different between these and more abstract concepts measured by the test.

While these findings are disheartening, it is important to note a critical issue that could have impacted the findings. The language skills of the deaf children who participated in this study are not specifically stated. The authors reported that the deaf children used either oral or total communication, but the children's background or experience with a system of signed communication or visual-spatial language is not described. Despite the fact that the examiner was a sign language interpreter, it is possible that the deaf students did not fully understand the directions of the test and that this resulted in decreased performance. In addition, this study did not consider the performance of deaf children from deaf families. Given natural language exposure from birth, it is possible that the scores of these children would have been higher. Nevertheless, the findings from this study do suggest a need to further examine the cause for deaf children's low performance on basic concept attainment.

2.1.4 Section Summary

In summary, early mathematical experiences are usually informal in nature (Tudge & Doucet, 2004), and can include everyday life experiences that encourage young children to count, build, share, and a myriad of other experiences that incorporate opportunities for the use of mathematical language and problem solving. Building a foundation of mathematical knowledge begins with learning how to "mathematize" one's environment (Joint Position Statement of NAEYC and NCTM, 2002), thereby making mathematical sense out of general experiences that include children's understanding of basic concepts. As research presented in this section indicates, it is evident that young hearing children know a great deal of mathematics by the time they begin formal schooling. Young hearing children understand counting principles (Gelman & Gallistel, 1978); are aware of the quantitative relationships represented by numbers (Sarnecka & Gelman, 2004); make judgments regarding the relationships between size and shape (Sophian, 2002); distinguish shapes and identify their attributes (Clements et al., 1999) as well as classify them (Deak et al., 2002); and demonstrate understanding of the relationships between sets quantitatively by the age of 5 years (Sophian & McCorgray, 1994). We also know that early learning contributes to later understanding (Bowman et al., 2001).

Less information is known regarding the mathematical skills and knowledge that young deaf children possess as they enter school. Research indicates that young deaf children possess near age-appropriate counting skills (Leybart & VanCutsem, 2002; Zarfaty et al., 2004) at the time they begin formal schooling; however, nothing is known regarding young deaf children's performance in the other mathematics content areas (i.e., Number and Operation; Geometry and Spatial Sense; Measurement; Patterns and Algebra; Displaying and Analyzing Data) described in the NAEYC and NCTM joint position statement (2002). In general, there is currently little information available regarding the informal knowledge that young deaf children arrive at school with both overall and in terms of mathematics specifically.

In terms of numerical knowledge, as research presented in this section indicates, young deaf children possess skills in the area of number and counting that are on-level with their hearing peers (Leybart & Van Cutsem, 2002; Zarfaty et al., 2004). However, as suggested by the NCTM standards documents and the position statement written jointly by NAEYC and NCTM (2002), there is more to early mathematics than just counting. It is possible that the onset of the achievement gap occurs before young deaf children begin formal schooling. In order to investigate the possibility that deaf children are at risk for lower levels of achievement before they even begin school more research is needed to examine their early understanding of mathematics concepts.

In addition, more information is needed regarding young deaf children's early knowledge in general. Research reported in this section indicates that knowledge of basic concepts is linked to later academic achievement (Breen, 1985; Howell & Bracken, 1992; Laughlin, 1995; Zucker & Riordan, 1990). It is possible that the reason for this connection between knowledge of basic concepts and academic achievement is that basic concepts form the "glue" that organizes one's knowledge and creates schemata. Research cited in this section also indicates that deaf children have a weakness in their knowledge of basic concepts (Bracken & Cato, 1986). Due to language differences, it is possible that deaf children arrive at school with a general difference in knowledge as compared with their hearing peers. However, it is unknown if complete access to language, as exists in the case of deaf children of deaf parents, would change this.

It is possible that young deaf children are entering school already "at risk" for failure. To investigate this possibility, there is a critical need for research to be done regarding the informal knowledge with which young deaf children enter school in general and in the area of mathematics specifically. In terms of specific areas within informal knowledge that may be important to investigate for deaf children, theory and research suggest that language and schema development could factor into deaf children's early mathematical knowledge (Huttenlocher et al., 1994; Sophian & McCorgray, 1994).

2.2 LEARNING THROUGH LANGUAGE

In considering factors that contribute to early mathematics, it is important to understand that early concepts that contribute to mathematical thinking are developed through language. This section will review language and schema development and consider research regarding language development in deaf children.

Theory and research suggest that language development begins with conceptual thinking. The appearance of the first generalized concept in a child's lexicon is a milestone. Prior to this point, the child thinks in terms of complexes in which any number of attributes may be used to link individual items (Vygotsky, 1962). The transition from thinking in complexes to thinking in terms of hierarchical relationships is demonstrated by Vygotsky (1962) with the following example: a child may first learn the word "flower" then the word "rose." Initially, there is no superordinate relationship between these words; when the child is thinking in terms of complexes, both exist on the same plane. However, when "flower" becomes generalized and includes "rose", the relationship between these words changes in the child's mind to a hierarchical relationship in which a rose is a type of flower. At this point the child becomes capable of generalized thought and language and will be able to remember concepts independently of specific words (Vygotsky, 1962).

Prior to understanding that relationships exist among words, young children may perceive words in terms of properties rather than symbolic representations of objects. There is evidence of this theory in a story Vygotsky tells of a child who first used the "word" *quah* to refer to a duck swimming in a pond. Next, this word was used to refer to any liquid, then a coin with an eagle on it, and then any round, coin-like object. In this chain-like complex, the word used does not maintain a stable referent. Each object has a property in common with another object, yet the attributes keep changing (Vygotsky, 1962).

Concept formation is more complicated than simply learning names for objects. According to Vygotsky (1962), "…memorizing words and connecting them with objects does not in itself lead to concept formation; for the process to begin, a problem must arise that cannot be solved otherwise than through the formation of new concepts (p. 54)." This is referred to by Piaget as *accommodation*, and is one of two processes used to describe concept development (Ginsburg & Opper, 1988).

The processes of *assimilation* and *accommodation* were first described by Piaget in the following manner: using *assimilation*, children interpret environmental information using the knowledge they already possess; *accommodation*, however, occurs when new information comes into conflict with existing knowledge. As a result of this conflict, prior knowledge must be reconstructed in order to include the new information (Ginsburg & Opper, 1988). Since concepts tend to develop first in the form of contradictions, the process of accommodation plays a critical role in concept development. Relationships that are used naturally are not noticed, we tend to notice relationships more explicitly when they cause an experience of discomfort or conflict (Vygotsky, 1962).

As concepts develop they must be mentally organized so that information can be accessed efficiently later on. The result can be thought of as a "web of connections" (Ginsburg & Baroody, 2003), or *schema*. A concrete example of the concept of schema is evident in the multitude of stars in the sky at night, and the manner by which ancient sailors located specific stars needed to navigate through open waters. As a whole it would have been impossible to remember the location of each specific star so constellations, or networks of stars, were established. Similar to schema, the constellations do not exist in the stars themselves but rather in the minds of the individuals who mentally create them (Feuerstein, 1980). Given these networks, a specific star could be found by locating the appropriate constellation and following the different pathways to the star.

There are three different processes through which individuals construct schema: *direct exposure*, *explanation*, and *individualized development of meaning* (Feurstein, 1997; Skemp, 1987). Through *direct exposure* individuals attain primary concepts. For example, upon touching the stove while mom is cooking, the child learns that it is hot. Through *explanation* and *individualized development of meaning,* secondary concepts are extracted from previously developed ideas and understandings (Skemp, 1987). For example, information is conveyed through explanation when someone tells the child not to touch the stove because it is hot. The child, therefore, does not need to directly experience touching the stove to discover this information. Depending on the nature of the explanation, however, this may or may not result in true learning. To encourage *individualized development of meaning*, an adult may direct the child's attention to the flames on the stove top or the red color of the pilot. Having attended to these characteristics, the child learns how to identify the concept of “hot” without actually touching the stove. Having developed an understanding of the relationship between the stove and the concept of “hot”, this child may later adapt this knowledge when s/he generalizes what s/he already knows about the temperature of the stove to determine that a pot which has just come off of the stove may also be hot.

Due to the lack of an opportunity to learn directly from the surrounding environment through the auditory sense, deaf and hearing children’s opportunities to learn through direct exposure may differ. To examine the differences between how learning may be manifested through direct exposure and individualized adaptation of meaning for young deaf and hearing children, it is helpful to examine the perspectives of both regarding a typical event experienced by young children, a birthday party. Both groups of children are exposed to the same direct learning experiences at the party; they encounter balloons, cake, presents and the other typical items associated with birthdays. For the hearing child, this event is also combined with the singing of “Happy Birthday,” which assists the child in acquiring a name for the day. Relatives may comment on the child’s age, and how big s/he has grown, thus the hearing child acquires another association with the day. Furthermore, a parent may explain why the child’s birthday is special, that it occurs once a year, etc. For the young deaf child who does not have full access to communication, however, this incidental communication is likely to be restricted. Without adequate communication, the deaf child’s learning is restricted to what is available visually; s/he will not acquire all of the information otherwise conveyed through language. Therefore, the deaf child’s schema of a birthday party is likely to be limited to the knowledge that was obtained through direct experience- the balloons, cake, and presents. Lacking linguistic exposure, s/he is unlikely to grasp the relationship between these items and the meaning of the day.

This experience is expressed by Gail Finn (1995), a Deaf woman who grew up in a hearing, non-signing family and attended an oral, residential school from the ages of 3-18 years. She describes her childhood schema of "birthday" as follows:

> I had no concept of time, therefore I had no idea of my birthday, my age, or the meaning of the clock's hands…Although my parents gave me a birthday party every year before the age of seven, I had not the slightest idea what the intention of a birthday celebration was, nor the meaning of a birthday (Finn, 1995, p.5).

2.2.1 Language as a Mediating Tool

While young children are exposed to an extraordinary wealth of visual information daily, it is the responsibility of parents, or other "older and wiser" individuals in the child's environment, to break up this onslaught of information and expose children to it in small, meaningful chunks (Marschark et al., 2002). This is mediation, and it requires interaction and communication in order to take place (Feuerstein, 1997). It is through asking and answering questions that children learn to derive meaning from their environment (Feuerstein, 1997). However, when there is little or no successful communication present in the home, the predominant role of conversation with the deaf child is often to obtain answers to direct questions or to gain specific information (Charlson, Bird & Strong, 1999). Deaf children may not be asked questions that encourage the development of thinking or language skills; rather, they are frequently asked to recall labels for items in their environment or directed to perform tasks. As described by Finn (1995):

> It is natural for hearing children and deaf children of deaf parents to seek causes and meanings; they constantly ask "Why?" "How?" "What if?" But deaf children of hearing

parents do not ask these questions. Rather, their mothers or teachers use meaningless monologues, asking “What’s this?” and “Do that” as if the child understood English (Finn, 1995, p.10).

Such uni-dimensional language does not encourage the higher level thinking skills such as comprehension, comparison, or evaluation necessary for informal learning (Feuerstein, 1997). Anecdotal evidence of the lack of this type of thinking is available in the book *Deaf Like Me* (1978). In this book, Tom Spradley depicts the experiences of his young deaf daughter and the frustration she experienced as she learned the routine of going to school. Young Lynn Spradley understood the concept of school. She knew she had to get up early, get dressed and go to wait at the bus stop. She did this every morning including Saturday and Sunday. Without a shared language that could be used to mediate and achieve mutual understanding between parent and child, Spradley describes the frustration he felt as he struggled to no avail to explain to his young deaf daughter that she did not go to school on weekends. It is likely that young Lynn experienced at least equivalent frustration as she waited for a school bus that, for some reason unknown to her, never came.

As the above examples indicate, young deaf children without adequate exposure to language may have difficulty noticing and/or learning from the environment around them; this is problematic as the ability to discover and/or recognize relationships and patterns in the surrounding world is perhaps the most critical component of conceptual development. Brooks and Brooks (2001), cite the words of psychologist George Kelly (1955) to describe the significance of this discovery:

> Man looks at this world through transparent patterns or templets (sic.), which he creates and then attempts to fit over the realities of which the world is composed. The fit is not always very good. Yet, without such patterns the world appears to be such an undifferentiated homogeneity that man is unable to make any sense out of it. Even a poor fit is more helpful to him than nothing at all (pp. 9-10).

Similarly, the critical role of the ability to recognize relationships is described by Hiebert and Lefvre (1986) as follows in their definition of conceptual knowledge as, "…a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information. Relationships pervade the individual facts and propositions so that all pieces of information are linked to some network (p.3)."

2.2.2 Developing Concepts through Language

As young children develop concepts and language, they begin to recognize relationships and their classification skills begin to emerge. As reported by Mervis, Johnson and Mervis (1994), the words or labels that young children use reflect a rudimentary understanding of classification and early awareness of the inequality of relationships among terms. Children's first labels often consist of names for the objects in their environment. For example, "pants" is the label for the article of clothing that one wears on one's legs. Eventually children begin to recognize the properties of objects in their environment more precisely. As this happens, categories are learned and given names (Blewitt, 1994). As children become aware of asymmetrical relationships existent among items in their everyday environment, an understanding of superordinate and subordinate categories begins to develop and children learn the names for specific kinds of things (Mervis et al., 1994). For example, the category of "pants" can be more finely discriminated into “jeans” and “sweats.” An asymmetric relationship exists between the labels “pants” and “jeans” as the second fits into the category defined by the first. However, the relationship between “jeans” and “sweats” is symmetrical as both are equivalent subordinate categories under the same superordinate term “pants.”

Evidence of the development of one hearing child’s use of categorical terminology in the avian domain (i.e., the young boy’s knowledge of birds), and the role his parents played in this development, is available in the longitudinal study of Ari reported by Mervis, Pani and Pani (2003). Data for this case study were collected in the form of diary entries recorded by parents and an aunt. According to data collected during this case study, Ari first comprehended the word “bird” at the age of 1 year and 6 months and produced this word for the first time 8 days later. This was the 12th word Ari learned to produce, the 6th label for an animal, and his 3rd word to label a member of the “bird” domain (i.e., “duck” and “owl” were produced first).

By the age of 16 months Ari had divided his concept of “bird” into 4 categories. “Ducks” included all waterfowl, large landfowl, large waterbirds, and medium or large shorebirds; “birds” included songbirds, medium-sized birds such as seagulls, penguins, crested cranes and all birds of prey except owls; and “owls” and “roosters” which included chickens and other medium-sized landfowl. There was some overlap in these four categories. Ari sometimes labeled eagles as owls, and quails were occasionally labeled as ducks.

At 17 months of age, Ari acquired three additional labels for basic level categories: chicken, penguin, and eagle. Up until 19 months, “chicken” was used as a synonym for “rooster”, while “bird” was on the same level as, rather than superordinate to, “penguin.” By 17½ months of age, Ari seemed to understand that an object can be a member of more than one category, a concept crucial to the understanding of subordinate level categories. He demonstrated this by referring to his pet cat both as "kitty" and by its name "Nutmeg." Now that he had this knowledge, Ari was ready to begin acquiring subordinate categories and their names, however, these terms were not produced based solely on deictic input (i.e., pointing) from adults in his environment. Rather, inclusive statements such as use of the word "kind" (e.g., a penguin is a *kind* of bird) or use of the indefinite article "a" (e.g., a canary is *a* bird) seemed to be most useful in developing Ari's understanding in this area. At 18 months, Ari knew how to label objects at a variety of hierarchical levels. He used his first indefinite article at 18 months of age and a short time later he began using the word "kind" inclusively.

By the age of 23 months, Ari knew that every bird belonged to a subordinate level category; he requested labels for their subordinate level names from the adults in his environment. By 24 months he had acquired 21 subordinate level bird names and their underlying categories. These included 15 types of songbirds, 2 kinds of ducks, and 4 kinds of medium-sized land birds (Mervis et al., 2003).

As information reported in this case study indicates, through use of language, Ari was learning the labels for various types of birds and, in the process, creating a conceptual schema to organize his knowledge. The context for Ari's interest in this topic may have been the learning experiences established by his family members. Ari was frequently brought to zoos and farms where he had multiple opportunities to experience wildlife. Ari's parents and grandparents had a bird feeder which was frequented by a variety of types of birds. In addition, Ari was surrounded by toys (e.g., a plush cardinal, bluebird, goldfinch, blackbird, seagull, eagle, vulture and wind up chicken), books, pictures, porcelain models and engravings that all resembled birds. These items were constantly labeled and/or described by the adults in Ari's environment. In addition, Ari was encouraged to notice characteristics that separated one category of birds from another. For example, while the label for “eagle” was seldom used with Ari, on one occasion an adult picked up a toy eagle and demonstrated the large sweeping movement of its flight. This contrasted with the smooth pattern Ari had come to attribute to the smaller songbirds (Mervis, et al., 2003).

As with Ari, without consciously thinking about it, parents present their young children with the labels they need to help them to classify the world around them in meaningful ways (Anglin,1995). For example, consider a young hearing child, barely old enough to walk, standing against a counter in a restaurant. Despite the environmental noise going on around her, when an individual calls out “Molly,” the child turns. In the approximately 14 months that the child has been alive she has learned that the sequence of sounds in “Molly” can be separated from the rest of the noise she hears. This pattern of sounds has meaning; “Molly” refers to her. It is likely that the child’s parents have encouraged this learning by continuously using the child’s name while interacting with her. Eventually, through normal, daily interaction, Molly will learn that different words can also refer to her. She may be called a “girl”, a “daughter”, or “Megan’s sister”.

As this example demonstrates, the impetus for the schema that young children create is likely to be the labels they know, use, and hear used in the world around them. The labels initially used by young children to name entities within their environment reflect how they define their world and demonstrate their developing knowledge of concepts. Anglin (1995) supports this theory by describing two factors that relate to children’s initial learning of category labels: <u>functional relevance</u> and <u>cultural significance.</u> The first factor relates to the idea that children first learn the labels that help them to classify the world in a way that makes sense and is useful to them. The second factor says that children will learn to name things in ways that make sense according to the cultural environment in which they are growing up, considering the knowledge that is valued by that culture.

Describing functional relevance, Anglin (1995) makes reference to the concepts of horizontal and vertical vocabulary development. These terms denote the level of generality indicated by a particular vocabulary word. While children may learn general terms prior to specific terminology (e.g., *cat* before *Persian*), if the specific term has functional relevance for the child (e.g., *Princess*, the name of the family cat), then it may be learned first. Parents assist children with this process by initially presenting them with terms which help to classify the world in meaningful ways (Anglin, 1995). If something is specifically relevant to the child, s/he will be taught the specific term which denotes that item (e.g., Princess). If an item is of limited functional relevance to the child it will be introduced more generally (e.g., *money* as compared with *dime* or *dollar*).

Discussing cultural significance, the relevance of specific terms may vary based on culture. Children growing up in an environment in which certain schemes of experience are particularly relevant to daily life will learn to categorize these experiences using different linguistic terminology (Anglin, 1995). For example, Eskimos use a variety of terms to label what the general population refers to as *snow*. These terms vary based on the specific nature of the precipitation; differences that are more likely to be salient to individuals who live in a cold climate than to those who live closer to the equator.

Further evidence of cultural significance is offered in research conducted by Dougherty (1978, 1979, as cited in Anglin, 1995) which compares the knowledge of botanical terminology of Mayan children with children raised in urban Berkeley, California. For children growing up in the Mayan environment, knowledge of plant life is essential, while in the urban community this information is only mildly significant for daily survival. Given this knowledge, it is not surprising that Mayan children were found to possess greater specific terminology for plant life than the urban raised children. For each group, environment influenced the words and concepts the children developed to make sense of and organize their world.

2.2.3 Deaf Children and Concept Development

The small percentage of deaf children who have deaf parents, and experience accessible communication from birth, are more likely to acquire labels for items in the world around them than deaf children with hearing parents (Marschark et al., 2002). The majority of deaf children however, are born into hearing families. In fact, less than five percent of deaf children have at least one deaf parent (GRI; 2003; Mitchell & Karchmer, 2004). More critical though is the fact that only 27% of families with a deaf child report regular use of sign language in the home (GRI, 2003). Therefore, the majority of deaf children are being raised in homes in which only a spoken language model, which may be inaccessible, is available. Since empirical evidence indicates the existence of a critical/optimal period for language acquisition during the first 3 to 5 years of life (Lenneberg, 1967; Newport, 1990), it may be concluded that the majority of deaf children are not being exposed to an accessible language model during the time period when it matters most.

Even when parents do decide to use signed communication with their deaf children, they often use a signed code that allows them to voice English while using signs, rather than American Sign Language (Swisher, 1984). A study by Swisher (1984) examined how effectively this communication practice was used by hearing mothers communicating with their young deaf children. The study sought to determine the consistency with which hearing mothers of deaf children signed what they voiced. Findings indicated that the message presented through signs was a simplified version of what was voiced. Therefore, if children did not have access to the full auditory message, they were unlikely to get it through the signs.

Due to the lack of consistent exposure to language, as described by Swisher (1984), young deaf children are likely to have a smaller vocabulary than their hearing peers. The implications of a smaller vocabulary size were examined in a study by Lederberg, Prezbindowski, and Spencer (2000). This study investigated the word-learning skills of 19 deaf and hard-of-hearing preschoolers between the ages of 3 and 6 years. Findings indicated that the children's ability to learn new words quickly was related to the size of their vocabulary; children with larger vocabularies learned new words faster. A possible explanation for this finding, discussed by the authors, is that word learning involves understanding that there is a predictable pattern or regularity to how words are mapped onto entities. For young deaf children with hearing parents (16 of the 19 children who participated in this study), even when signs are used for communication they may not be used with consistent accuracy, meaning that "mispronunciations" in handshape, location, and/or movement may occur as the parent him/herself struggles to learn new sign vocabulary. This being the case, it may be difficult for the child to find regularity in how words are mapped onto entities. In addition, as discussed by the authors, knowledge of basic-level categories may need to develop before the child can learn effective word-learning strategies. Categorical knowledge allows young children to recognize the difference between new words mapped onto unfamiliar objects and adjectives mapped onto familiar objects; for example, knowing that a <u>blue</u> bird differs from a <u>red</u> bird only in color, it is still a bird. This study however, did not include an examination of young deaf children's classification skills. More research is needed to investigate how young deaf children categorically organize their world, and the role of language, spoken or signed, in facilitating this process.

Since hierarchical relationships are expressed differently in American Sign Language (ASL) than in spoken English, this language difference could influence how native signing young deaf children mentally organize concepts. In ASL, superordinate concepts tend to be represented by compounding basic level signs. For example, the sign for “transportation,” may be formed by linking the three basic level signs CAR+PLANE+TRAIN ETC (Klima & Bellugi, 1979). Currently, there is no research indicating what influence this difference has on deaf children’s cognitive organization of superordinate level concepts.

Recognizing the value of early exposure to sign language, Bandurski and Galkowski (2004) conducted a study examining the influence of early and consistent exposure to sign language on the development of a conceptual system in deaf children. When the ability of deaf children to understand analogical reasoning was examined, findings indicated that early and consistent exposure to sign language resulted in the development of verbal, numerical, and spatial reasoning by analogy skills that were almost equivalent to that of hearing children. However, the authors reported that all deaf children received the task presented through sign language. For the deaf children with hearing parents who participated in this study, sign language may or may not have been their primary means of communication. Therefore, the reason that this group of children was less successful on the tasks they were given could have been that they did not understand them. Nevertheless, the findings from this study are useful in indicating the value of early language exposure.

Additional studies in the area of cognition and deafness also indicate that language plays a substantial role in concept development for deaf children. Findings from a literature review on cognition in deaf children and adults indicate that deaf individuals perform similarly to their hearing peers on uni-dimensional tasks; however, when two dimensions need to be considered, color and shape for example, deaf individuals perform at a lower level (Ottem, 1980).

Differences between deaf and hearing children's concept development is evident in another study on cognition done by Marschark and Everhart (1999). In this study, Marschark and Everhart (1999) examined deaf children's ability to ask alternative-limiting questions during a game of "Twenty Questions." Deaf and hearing children between the ages of 7 and 14 years were presented with a set of 42 pictures. The examiner, or in the case of the younger children, a puppet manipulated by the examiner, selected one picture from an identical set of pictures hidden in an envelope. Children were instructed to ask yes/no questions to help them discover which of the pictures the examiner had selected. These questions were later analyzed for their "alternative-limiting" potential. Children who were successful at selecting the correct picture used questions that limited the number of options available to them, for example, "Is it an animal?" (Marschark & Everhart, 1999). Such a question involves understanding the hierarchical-inclusive relationship, between "animal" and "dog", "rabbit", "fish", "cow" or "bird." Deaf children in the study, however, were more likely to ask questions that could best be described as isolated "guesses," for example, "Is it a rabbit?" These findings suggest that the deaf children considered each question as a separate unit. In comparison to the findings from the study by Sophian and McCorgray (1994) discussed previously, in which young children were found to develop an understanding of superordinate and basic-level relationships in situations presented mathematically between the ages of 4 and 5 years thereby allowing them to consider part-whole relationships, the deaf children in the Marschark and Everhart (1999) study, did not appear to have developed this understanding even though they were older. Rather than considering the *whole* purpose of the task, (i.e., determining the selected picture), deaf children viewed each *part* (i.e., isolated guesses) individually (Marschark et al., 2002). Although, as reported by the authors, all children in this study used sign language as their primary means of communication, none were reported to be native signers, and sign language skill was not evaluated. It is possible that the ability to successfully learn the winning strategy of the "20 Questions" game could be attributed to language knowledge and experience rather than hearing status; however, this can not be determined from this study.

Since classification skills are an early indicator of mathematical ability (Deak et al., 2002; Joint Position statement of NAEYC and NCTM, 2002), classification is another area to consider when looking for factors that contribute to the achievement gap in deaf children's mathematical performance. While research relating to the development of classification skills in deaf children is limited, the majority of findings thus far indicate that deaf children perform differently from, and generally at a lower level, than their hearing peers in this area. Unlike the studies with hearing children reported previously (Mervis, et al., 1994, 2003), research investigating deaf children's use of classification is related to the categorization of concrete objects, rather than the use of language.

Research by Furth (1961) examined the classification skills of 180 deaf and 180 hearing children between the ages of 7 and 12 years. Children in this study participated in three classification tasks: *sameness*, *symmetry* and *opposition*. No receptive or expressive language was required for participation in these tasks. For the *sameness* task, children were given two lids with simple figures drawn on them. One lid contained two of the same figure; the other contained two figures that were different. The child was instructed to identify the lid on which the figures were the same. For the *symmetry* task, the child was shown two cards with drawings on them, one drawing was symmetrical the other was not. The child was instructed to identify the symmetrical drawing. On the *opposition* task, four round discs differing in size were placed in front of the child. The experimenter would point to either the largest or smallest of the discs. The child was expected to choose the disc opposite in size to the one chosen by the examiner.

Results indicated that while deaf and hearing children performed similarly on the first two tasks, the deaf children had substantial difficulty with the opposition task. The rationale, according to Furth (1961), was that, due to language exposure, hearing children are more familiar with the concept of 'opposite' than are deaf children. In general, children tend to learn words for extremes for example, hot and cold, good and bad, tall and short, before they can characterize the dimensions of those extremes. Not having exposure to a full language model, deaf children may miss out on these conceptual variations and need to specifically be taught the concept of opposition. While this study emphasized that no expressive or receptive language was required for the tasks presented in this study, it minimized the value of language in the children's background. The abilities of deaf children with deaf parents, who experienced full exposure to language since birth, albeit a visual-spatial rather than an auditory-oral, language were not considered.

In general, research regarding young deaf children's classification skills is limited. Only two studies were found regarding the classification skills of preschool-age deaf children. Best (1972, 1975) utilized a classification task to examine young deaf children's ability to classify picture cards into similar groups. For this task, different levels of classification were required including: 1) classifying identical items (cards in which the two pictures were exactly the same); and 2) hierarchical classification which required knowledge of subordinate classes within a superordinate class, (i.e., recognizing a pig and horse as animals). Findings from these studies indicated that a slight developmental lag between deaf and hearing children was already evident at the age of 3-4 years. The tasks used in these studies however, based knowledge of classification on an understanding of semantic concepts. Categories were defined by their labels. The tasks required children to make a forced choice for an item belonging to either of two categories (1975), or to answer a yes/no question (1972). Such tasks impose pre-constructed categories on children. While the findings from such studies are useful in analyzing deaf children's abilities to recognize pre-determined categories, they do not provide information on the cognitive networks constructed by the children themselves.

A study by Kritzer (in press), was an attempt to address this limitation and to examine the cognitive frameworks organized by deaf children. In this study, nine deaf children between the ages of 5 and 11 years were presented with tasks that required them to sort items into categories that were not predetermined.

Children were presented with three sets of materials, ranging from concrete to more abstract in nature, and instructed to group the materials in ways which made sense to them. Following a Piagetian scheme, data were coded according to the following specifications: *Graphic collections*-groupings based on perception or spatial relationships as demonstrated through the creation of pairs or pictures out of the materials to be sorted. Here, spatial arrangement was a critical aspect of the child's sorting; and *Non-graphic collections*- groupings in which some attempt was made to sort materials into groups which were not dependent upon spatial arrangement. Non-graphic collections were further divided into four stages (Phillips & Phillips, 1996):

- Stage 1 consisted of collections based on varied criteria which were not mutually exclusive, that is, could overlap. For example, when sorting a group of colored shapes, a child could include a group of "blue things" and a group of "triangles." This is a problem if a 'blue triangle' is among the items that the child must sort. At this stage, all materials to be sorted may not be included in the child's arrangement.

- Stage 2 consisted of a large number of small collections. At this stage, each item commonly gets its own group. For example, if given colored shapes to sort, the child may establish a group of blue squares, red squares, yellow rectangles, and so on. None of the criteria overlapped and no items were left unassigned.
- Stage 3 groupings were based on **one** criterion. For example, given colored shapes, the child sorted the items by shape or by color.
- Stage 4 groupings were based on multiple criteria. For example, the child who can sort shapes based on color is also able to re-sort the same items based on shape. At this stage, the child realizes that a grouping does not cease to exist simply because its members have been rearranged.

Findings indicated that deaf children may experience substantial limitations in pre-classification skills. No child in this study demonstrated an ability to sort items into groups beyond non-graphic stage 3. While children were, in some cases, able to separate groups based on one criterion, they were unable to rearrange the items to sort them according to different criteria. Not surprisingly, as the materials used for sorting became more abstract, overall performance declined. Children demonstrated a higher level of classification on tasks that were more concrete in nature.

A possible explanation for deaf children's decline in performance with the use of abstract materials could be that the items to be sorted needed to be considered multi-dimensionally. For example, in order to sort the colored shapes, both color and shape were salient features that needed to be considered. As discussed previously, when deaf individuals are required to consider two or more dimensions of objects simultaneously, they often perform at a lower level than their hearing peers (Ottem, 1980).

2.2.4 Section Summary

As research described in this section indicates, it is likely that the size of a child's lexicon influences the relationships that s/he is able to recognize in the surrounding world and the mental schemas that s/he is able to create (Lederberg et al., 2000; Mervis et al., 1994). As research by Mervis et al. (1994) cited in this section indicates, we know that young hearing children are able to demonstrate knowledge of superordinate and subordinate relationships among words. This ability was also evident in Mervis et al.'s (2003) discussion of Ari and the categories of words he used before the age of 2 years. Since classification studies done with deaf children have used concrete materials rather than language (Best, 1972, 1975; Furth, 1961), it is not known what these language relationships look like for deaf children. Because research evidence with hearing children suggests a relationship between language and early mathematics concept development (Huttenlocher et al., 1994; Sophian & McCorgray, 1994) however, this is an area worthy of further investigation.

More research is also needed to examine young deaf children's concept development in general. Since classification skills are required to organize concepts and create schema (Mervis, 1994), and classification is also a critical part of early mathematics (Deak et al., 2002; Joint Position Statement of NAEYC and NCTM, 2002), it is reasonable that, given differences in language acquisition, deaf children's early concept development is another area to consider when looking for factors that contribute to the achievement gap. It is possible that, given language limitations, young deaf children are acquiring labels or concepts individually without learning the relationships among them. This may have an impact on further learning and concept development as complete schemas, or networks of related information, are not developing.

2.3 CONTEXTS FOR EARLY LEARNING

Since the quality of early learning and the informal mathematics knowledge that young children bring into the classroom can influence their early concept development, it is also important to consider the contexts in which early information is learned. Theory and research suggest that the home environment is critical to later learning (Hart & Risley, 1995, 1999, 2003; Jimerson et al., 1999); therefore, any examination of young children's early knowledge must also include an investigation of the environment in which this information is acquired. As will be discussed in this section, mathematical knowledge can develop informally within the context of a nurturing environment that provides rich learning experiences to stimulate early learning (Aubrey, Bottle & Godfrey, 2003; Phillips & Anderson, 1993; Saxe, Guberman & Gearhart, 1987; Walkerdine, 1988). Mediated Learning Experiences (MLE) in particular may provide such a valuable context through which early learning is transmitted (Ben-Hur, 1998; Feuerstein, 1997; Klein, 2000, 1991).

Findings from a longitudinal study by Hart and Risley (1995, 1999, 2003) indicate the critical value of the learning that occurs in the home before the child begins formal schooling through exposure to vocabulary alone. The Hart and Risley (1995,1999, 2003) study investigated the vocabulary development of children in 42 diverse American families for 2 ½ years, from approximately the time when children said their first word until they were about 3 years old.

Findings from this study indicated that children from homes with lower socioeconomic status (SES) status learned fewer words and acquired vocabulary more slowly. Children from families at the higher end of the SES spectrum were calculated to have heard 30 million more words than children from families at the lower end. Follow-up data indicated that measures of achievement when the children were 3 years old were predictive of achievement in third grade. Perhaps the most critical finding from this study is that parenting behaviors, including diversity of vocabulary used, feedback, guidance, a general emphasis on use of language, and overall responsiveness to the child, were strongly predictive of children's later achievement.

2.3.1 Learning Mathematics in the Home

In terms of mathematics, research indicates that informal learning and parenting behaviors also occur in the home to stimulate mathematics awareness (Aubrey, et al., 2003; Phillips & Anderson, 1993; Saxe et al., 1987; Walkerdine, 1988). According to Walkerdine (1988), parents engage in two different types of instructional tasks, *instrumental* and *pedagogic,* when interacting with their children to relay mathematical information. In an *instrumental* task mathematics is used incidentally. For example, using the domain of number, when asking the child to set the table for dinner, a parent might mention that 5 plates are needed. Instrumental tasks emerge naturally from daily activities. This is in contrast to *pedagogic* tasks which are contrived to be instructional in nature. Again using the domain of number, an example of a pedagogic task may be counting blocks as the child plays with them. In this task, counting is the main focus of the activity.

Regardless of whether or not a parent views a task as explicitly mathematical in nature, young children are constantly surrounded by an instrumental use of mathematical language at home, specifically vocabulary referring to relational concepts. Overtime, children are likely to incorporate the use of this mathematical vocabulary into their own language use. Support for this can be found in the analysis of a language corpus done by Walkerdine (1988). During a conversation with her mother, a 3.9-year- old child was found to use a variety of relational terms to describe size and quantity. For example, to describe the concept "big," and degrees of "bigness," the child used ten different terms (i.e., big, bigger, biggest, bit big, very big, as big as, not big enough, not big, bit bigger, too big). Her use was similar for the concept of "small." The child's accurate use of these vocabulary terms indicates that she is developing a relational understanding of size. She knows that not everything can be described as "big"; rather there are degrees of "bigness." Other relational terms used in the same language corpus were "same" and "different." "Same" was used 17 times, sixteen of which referred to equivalence. "Different" was used 7 times; all uses related to equivalence. Based on only one child, an early conceptual understanding of mathematics cannot be generalized; however, the examples presented above do indicate that young children's early conceptual understanding of mathematics can be expressed through the use of everyday vocabulary.

Findings from a case study by Phillips and Anderson (1993) indicate that a common activity shared between parents and children, reading books, can also be instrumental in relaying mathematical information as it lends itself to mathematical discussions. The following exchange between a mother and her 3.5-year-old daughter was recorded during the reading of <u>The Three Little Pigs.</u>

Mom: Let's see how we can remember which pig is Pig #1. Look, he's dressed in yellow.

Jacklyn: And his house is yellow too. They're the same! (p. 137)

In this exchange, the mother effectively relays mathematical information to her daughter by encouraging her to recognize relationships in the story, (i.e., the way that information about each pig is organized) and use classification as an organizational tool. While not giving away the answer, the mother encourages her child to think by drawing her daughter's attention to the color of the pig's clothing, thereby encouraging the young girl to notice other uses of this color.

As described by Phillips and Anderson (1993), "…finding clues to relationships… (p. 137)" is a skill frequently needed during problem solving. An individual must be able to sort out information that is and is not critical to the problem in order to arrive at a solution. While adults may recognize relationships and make connections automatically, young children are not able to do this. Relationships must be brought to young children's attention in order to broaden the connections that they are able to make on their own.

Also during book reading experiences, Jacklyn's mother tended to draw her daughter's attention to the book's author and illustrator. It later became a fun, independent pastime for this girl to sort her books by author and/or illustrator (Phillips & Anderson, 1993). The ability to do this indicates the young girl's growing understanding of one way in which materials may be classified.

Additional case studies describing young children's developing competencies in mathematics at home indicate that parents tend to engage their children in a variety of pedagogic games and activities related to number. In a longitudinal case study of two young children from the time they were 18 months old until they were 48 months old, Aubrey, Bottle and Godfrey (2003) concluded that mothers included mathematics development in the home by frequently engaging their children's interest in counting rhymes, counting books, puzzles, and games.

Additionally, these two young children were involved, at least incidentally, in household activities such as setting the table and following a recipe while the mother was cooking.

Through the use of interviews with 400 mothers of preschool-age children, Saxe, Guberman and Gearhart (1987) found that mothers frequently incorporated numbers into their young children's daily routines through play, playing board games and invented number games such as counting steps while walking, or reading numbers on license plates. Nearly the entire sample of mothers reported that their children engaged in self-initiated number activities more than once a week (i.e., counting snacks, toys, etc.).

2.3.2 Environmental Learning for Deaf Children

As the above studies indicate, children acquire a great deal of information informally through active exploration of the environment and their experiences with the people and things around them. Yet, even in the same environment as their hearing peers, deaf children may have experiences that are substantially different in quality (Marschark et al., 2002). Lacking one modality through which to acquire information, deaf children are exposed to substantially less information than hearing children. A deaf child may observe situations in the world around him/her that appear to happen "magically" without cause or explanation. For example, Daddy walks to the door, and there is someone there (the child never heard the doorbell) or Mommy picks up the phone and her lips start moving (the child never heard the phone ring and does not hear his/her mother's voice).

Even when sign language is used in the home, one parent may be the primary communicator (Evans, 1994, 1995, 1998). This means that deaf children are frequently excluded from dinner table conversations and other social, communicative experiences where informal learning occurs. This situation is effectively described by Judith Evans (1994, 1995, 1998) in her case-study of a 7 year old deaf girl, Kristen.

Kristen was growing up in a large family with seven hearing siblings, however only her mother signed. For this reason, Kristen was often left out of much of the communication that happened in her home. In an analysis of Kristen's interactive episodes with various members of her family, it was found that she frequently did not have access to a primary communication partner who would communicate the situation to her. While her mother recognized that Kristen was often left out of family communication, she stated that this was part of Kristen's "…learning to deal with her deafness (Evans, 1995)…"

This experience of being left out of family interaction is also described by Foster (1989 as cited in Foster, 1996) in recounting the experience of being deaf and eating at a table with hearing people:

> …I'd say "what did you say?" and they'd say "wait a minute." And I'd wait and wait and wait. I'd say, "Hey, what are you guys talking about?" They'd say, "Wait a minute." And [then] they'd say, "Well, what do you want?" You know, they should at least come back and finish the conversation, but they do that over and over…so I give up…I just ignored it and eat (sic.) (1996, Foster, p. 229).

Isolation within the family is described again by Foster (1989, as cited in Foster, 1996) in the following:

> My family, there wasn't a lot of opportunity to talk, really not much. They would talk, talk, talk. My family would be talking away and I would just sit there…I would have to say, "What did they say?" And [they would tell me, but] in real simple sentences, not fully,

just a simple explanation. I am not interested in that. I am interested in the specifics of what you're saying, I am curious, what did they say (1996, Foster, p. 165)?

When interaction does occur between hearing parents and their deaf children, the interaction style may not be effective in stimulating informal learning. In a study by Jamieson (1994), three matched groups (i.e., hearing mothers with hearing children, hearing mothers with deaf children and deaf mothers with deaf children) were observed interacting with their preschool-age children while working on a problem-solving task. While participating in the activity, deaf mothers were more likely than hearing mothers to get their child's visual attention before communicating (i.e., signing). They would direct the child's attention to the object under discussion but again wait for attention before continuing to communicate. The authors refer to this is as a "sequential" visual communication approach as compared with the "simultaneous" approach used by the hearing mothers. Hearing mothers were more likely to interact with their deaf children the way they would with hearing children, talking about the activity while the child's attention was focused on the activity. Furthermore, the authors state that, similar to the hearing parents with hearing children, the deaf parents with deaf children appeared to be focusing on mediating the *process* involved with the task. In comparison, the hearing parents with deaf children appeared to be more focused on the *product* or outcome of the interaction. Overall, of the three groups, hearing mothers with deaf children were found to be the least likely to adapt their interaction techniques to meet their children's needs. This may explain why deaf children with hearing parents demonstrated the most passivity during the task. However, it is important to note that the deaf children with hearing parents who participated in this study were all enrolled in an oral-aural preschool. This being the case, it is likely that the hearing mothers considered their children to be developing language “normally” using the auditory-oral pathway, thereby reducing the need to obtain visual attention before communicating with their children.

However, a study by Wedell-Monnig and Lumley (1980) found similar results despite the fact that the mothers of the majority of deaf children who participated in this study (4 out of 6) were learning sign communication, although they did not demonstrate fluency in the use of the language. In this study, six deaf children with hearing mothers and six hearing children with hearing mothers were observed during free-play situations in a laboratory playroom. All children were between the ages of 13.2 and 29.2 months of age. Mother-child pairs were observed 4 times over the course of 2 months. Overall findings indicated that deaf children were more passive and less actively involved in the interaction than their hearing peers. Similar to the findings from the Jamieson study (1994), hearing mothers with deaf children were found to play a more dominant role in the interaction with their children. In both studies however, the child’s position in the family is not stated. It is possible that the hearing mothers who participated in each study were demonstrating the interaction style that they would use to interact with any child, regardless of hearing status. If the deaf child was the only child in the family, or the oldest, it is possible that the mothers had simply not yet learned how to interact productively with a young child.

Additional studies also indicate that hearing mothers with deaf children are less likely to follow their infant’s lead during an interactive exchange (Spencer, Bodner-Johnson, & Gutfreund, 1992; Spencer & Gutfreund, 1990). Fourteen mother-child dyads participated in the study conducted by Spencer, Johnson and Gutfreund (1992); four dyads in which mother and infant were both deaf, three dyads with hearing mothers and deaf children, and seven dyads in which both mother and child were hearing. All infants participating in the study were between

12 and 13 months old. Data were obtained from a 3 minute videotaped interaction session between each mother and child dyad. Data were coded for the mother's reaction to her infant's eye-gaze. Findings from this study indicated that hearing mothers with deaf children were found to respond to their infant's eye-gaze significantly less than either of the other two groups. An example of this type of interactive exchange is provided by one dyad in which the deaf infant appears to be intrigued by the seat-belt of his highchair while his hearing mother attempts repeatedly to redirect his attention to learning the sign for EYE.

There are a variety of reasons why hearing mothers may be more controlling in interactions with their deaf children. First, it is possible that they have not learned how to adapt their interaction styles to meet the needs of their deaf children; hearing parents with deaf children need to learn to adapt to their deaf child's need to access information sequentially, rather than simultaneously the way that hearing children do (Swisher, 1992). Second, parents may feel uncomfortable with raising a child whose hearing status differs from their own; this uneasiness could lead to an unconscious desire to control the things that they have the capacity to control, such as the communicative exchange (Spencer & Gutfreund, 1990).

2.3.3 Mediated Learning Experiences

The described challenges that hearing parents experience when interacting with their young deaf children are likely to influence the mediated learning experiences that these parents are capable of providing. This is critical since mediated learning experiences provide a valuable context through which early learning is transmitted (Ben-Hur, 1998; Feuerstein, 1997; Klein, 2000, 1991).

Similar to what was discussed previously, according to Feuerstein (1997), there are two main types of learning experiences from which children can learn: *direct exposure* and the *mediated learning experience* (MLE). *Direct exposure* involves direct interaction with stimuli. Only two "participants" are necessary, the individual and the stimuli; for example, a young child (the individual) playing independently with a small car (the stimulus). The mediated learning experience includes a human factor. For a MLE to occur, three "participants" are necessary- the child, the stimuli, and a human mediator. The mediator places him/herself between the child and the environment (the stimuli) in order to make an experience more meaningful (Ben-Hur, 1998). For example, given the above situation, the child is playing with the same small car, however, now a mediator is involved. This individual will serve as a bridge between the child and the toy. For example, the mediator may comment on the size of the car, "This car is *small*, -where is your *big* car?" thereby exposing the child to the relationship established by size. The mediator could also comment on the color of the car, "Look, your car is *blue* like Daddy's!" in so doing, encouraging the child to notice a relationship established by color. As this example indicates, a MLE involves more than just an interaction between an adult and a child. Effective mediators draw children's attention to specific stimuli, in this manner teaching them how to perceive meaning from the environment. Such individuals set up MLEs in ways that teach children how to think (Ben-Hur, 1998).

There are eleven attributes that, according to Feuerstein (1997), distinguish mediated learning experiences from other interactions: 1) Interaction/Reciprocity; 2) Transcendence; 3) Mediation of meaning; 4) Mediation of feelings of competence; 5) Mediation of regulation and control of behavior; 6) Mediation of sharing behavior; 7) Mediation of individuation and psychological differentiation; 8) Mediation of goal-seeking, goal-setting, goal-planning, and goal-achieving behavior; 9) Mediation of challenge: the search for novelty and complexity; 10) Mediation of awareness of the human being as a changing entity; and 11) Mediation of an optimistic alternative. The first three characteristics: Intentionality/Reciprocity; Transcendence; and Meaning are noted as the most critical distinguishing features of mediated learning experiences (Feuerstein, 1997), and therefore, are the only characteristics that will be described in detail here. These characteristics can also be referred to as the *where/when, why,* and *how,* respectively, of the learning experience. The *what*, or content, is of minimal importance. Since children cannot be directly taught every piece of knowledge they will ever need, they must learn *how* to learn. This process of learning to self-construct knowledge is the purpose of the mediated learning experience and is described in more detail below.

The characteristic of *intentionality and reciprocity* refers to the *where* and *when,* or manner in which the mediator sets up a learning experience for a child. The learning environment is the critical feature at this level of the mediated learning experience. The mediating adult will organize the environment or learning situation in such a manner as to maximize learning. For example, while eating is required for survival, the physical consumption of food can occur anywhere and under almost any condition. A mediating parent, however, will tend to establish conditions and routines associated with mealtime. These routines may include setting the table, setting up a specific time for each meal, eating only at mealtimes, etc. The intention of mealtime routines is not just to feed the child, but to mediate cultural values as well (Feuerstein, 1997). In addition, the attentive parent "reads" and responds to the child, perhaps by taking his/her food preferences into consideration when planning meals and/or including him/her in the process of meal preparation.

A mediated learning experience can also include the characteristic of *transcendence* in asking *why* the child needs this learning experience. Explanations are the critical feature at this level of the mediated learning experience. The meaning of the mediated learning experience goes beyond, or *transcends*, the immediate situation through use of an explanation that may include a long-term learning objective (Feuerstein, 1997). For example, as part of the mealtime routine, parents might tell their children to wash their hands before eating. A mediating parent would also explain that hand-washing is important in order to kill germs, thereby establishing the potential for the development of a healthy life-long habit.

At the deepest level of the three characteristics of a mediated learning experience is *meaning* (Feuerstein, 1997), that is how children apply their concepts or theories about the way the world works to their observations (Ben-Hur, 1998). Questioning is the critical feature of this level of the mediated learning experience. Finding meaning in experiences occurs as children learn to compare situations, group and regroup occurrences, consider *where*, *when* and *why* events occur and what the relationships between them are. Children may only learn to experience the world this way when they are encouraged to do so by an effective mediator. For example, a young child may learn to interpret meaning as an attentive adult encourages him/her to compare the experience of mealtime at home with eating out in a restaurant. When the developing child learns to question the world around him/her and learns to ask *why*, *what* or *how*, s/he has learned to derive meaning from the surrounding environment.

Through mediation, young children learn how to interact with the environment. They learn *how* and *where* to look for information. In general, they learn *how* to learn so when in a "direct exposure" learning situation they know what to do. Such children know how to build networks by looking for relationships between events because these relationships have been pointed out to them; they know how to ask questions because questions have been asked of them; and in general, they know how to interact with the world because they have been encouraged to be actively involved with their own learning.

Studies regarding the use of meditated learning experiences in the home environment are limited. Klein (2000, 1991) investigated the influence of mediated learning experiences on young children's learning. Specifically, Klein (2000, 1991) examined the influence of an intervention program designed to enhance use of mediated learning experience in the home on the learning of children with a very low birth weight. In this study, mothers of 1 year old children were trained in the use of mediation techniques. In a follow-up study when the children were 4 years old, children of mothers in the experimental group demonstrated higher cognitive performance than a control group of children whose mothers had not been trained.

In the school setting, a number of studies have examined the impact of mediated learning experiences on learning. For example, a study by Schur, Skuy, Zietsman, and Fridjhon (2002), examined the use of mediated learning experience and constructivism while teaching science concepts to low-functioning 9th grade students. This study examined the influence of a science Astronomy curriculum designed on a foundation of constructivism and mediated learning experiences on enhancing the cognitive abilities of a group of low-functioning high school students. Results indicated that, in comparison to a control group, students in the experimental group demonstrated enhanced cognitive functioning in the context of Astronomy in addition to improved problem solving skills. Implementation of instrumentation making use of mediated learning experiences also indicates that the methodology is beneficial for preschool-age children. A study by Tzuriel and Caspi (1992) found that on post-use of instrumentation involving mediated learning experiences, deaf preschoolers performed higher on tests of cognitive functioning. This study, however, made use of a specific instructional instrument. More research is needed regarding the benefits of mediated-learning experiences in natural learning situations.

With deaf students, research findings indicate that mediated learning experiences within the school environment have been effective in improving the cognitive performance of deaf students. One way this has been studied is through use of Feuerstein's Instrumental Enrichment program with deaf adolescents. All of the studies described here focus on older children as that is the population for whom the Instrumental Enrichment program was designed. Although an early childhood version of the curriculum is now available (IRI, 2006), this program is too new for research regarding its use to be available.

The Instrumental Enrichment (IE) program was designed as a means of changing the cognitive structures of individuals who demonstrate cognitive weaknesses. Individuals with passive learning styles are encouraged to become more in control of their own learning. This is accomplished through the process of cognitive modifiability. The ultimate goal of this program is to teach individuals how to learn through direct experience by improving their habits of mind (Feuerstein, 1980). Sub-goals of the program include correcting deficient functions, increasing intrinsic motivation, encouraging reflective thinking, and improving overall attitude towards learning (Feuerstein, 1980).

The Instrumental Enrichment program is directed towards adolescents and is taught in 1 hour lessons, 3-5 days a week, for 2-3 years. The instruments which compose the program include topics such as cue recognition, categorization, comparison, logical relationships, perspective taking, and analogical thinking. Each instrument encourages precision, accuracy and the restraint of impulsivity (Feuerstein, 1980). The purpose of the instruments is to teach thinking processes. The instruments are, therefore, relatively content-free. However, teachers are encouraged to bridge learning from Instrumental Enrichment lessons to other parts of the school day.

While no study was found involving the use of the Instrumental Enrichment program with hearing children who did not demonstrate some form of cognitive disability, research evidence indicates that the Instrumental Enrichment program has been successful in enhancing the metacognitive skills of deaf adolescents nationally (Jonas & Martin, 1984; Martin & Jonas, 1986) and internationally (Martin, Craft, & Sheng, 2001). However, none of the described studies examined the relationship between participation in the Instrumental Enrichment program and academic achievement longitudinally. Research is needed to examine the long-term benefits of participation in the Instrumental Enrichment program.

No research is currently available regarding the use of mediated learning experiences in the homes of young deaf children. Using mediated learning experiences to teach young deaf children successful patterns of thinking, or how to perceive meaning from their environment, in early childhood might prove to be beneficial to their later learning. Similar to the studies by Klein (2000, 1991), it is possible that enhancing the mediated learning experiences (including characteristics of intentionality and reciprocity, transcendence, and meaning, specifically) that young deaf children experience in the home would result in higher levels of cognitive performance by the time the children reach school age.

2.3.4 Section Summary

As theory and research discussed in this section indicate, the home environment is critical to later learning (Hart & Risley, 1995, 1999, 2003; Jimerson et al., 1999) and the quality of early learning experiences can influence the development of informal mathematics knowledge

(Aubrey, et al., 2003; Phillips & Anderson, 1993; Saxe et al., 1987; Walkerdine, 1988). Mediated learning experiences (MLE) in particular provide a valuable context through which early learning is transmitted (Ben-Hur, 1998; Feuerstein, 1997; Klein, 2000, 1991; Schur et al., 2002) both in the classroom (Schur et al., 2002) and in the home (Klein, 2000, 1991). While research indicates that mediated learning experiences have occurred in the classroom for deaf students (Jonas & Martin, 1984; Martin & Jonas, 1986; Martin et al., 2001), no research data is currently available regarding the mediated learning experiences that young deaf children are exposed to in their home environment or how these experiences influence the informal knowledge they bring to formal schooling with them, including knowledge of basic concepts and early mathematics. To isolate factors that could contribute to young deaf children's risk for low achievement in the area of mathematics at school-age, this is a critical area where more research is needed.

2.4 CHAPTER SUMMARY

As discussed in this chapter, in order to address the low achievement levels of deaf students in the area of mathematics, it is necessary to investigate when these low achievement levels begin and the basis of them. Only through this process can a plan be generated to address this problem. As the theory and research presented in this chapter indicate, there is currently insufficient research data available to confirm the possibility that young deaf children are beginning formal schooling already at risk for low achievement, but there is a strong indication that they might be.

As research presented in this section suggests, it is evident that young children in general know a great deal of informal mathematics by the time they begin formal schooling. Young children understand counting principles (Gelman & Gallistel, 1978); are aware of the quantitative relationships represented by numbers (Sarnecka & Gelman, 2004); make judgments regarding the relationships between size and shape (Sophian, 2002); distinguish shapes and identify their attributes (Clements et al., 1999) as well as classify them (Deak et al., 2002); and demonstrate understanding of the relationships between sets quantitatively by the age of 5 years (Sophian & McCorgray, 1994). Less information is available regarding the mathematical skills and knowledge that young deaf children possess as they enter school. Research indicates that young deaf children possess near age-appropriate counting skills (Leybart & VanCutsem, 2002; Zarfaty et al., 2004) at the time they begin formal schooling; however nothing is known regarding their performance in the other mathematics content areas described in the NAEYC and NCTM joint position statement (2002) (i.e., Number and Operation; Geometry and Spatial Sense; Measurement; Patterns and Algebra; Displaying and Analyzing Data). In addition, more information is needed regarding young deaf children's early knowledge in general. Research reported in this section indicates that knowledge of basic concepts is linked to later academic achievement (Breen, 1985; Howell & Bracken, 1992; Laughlin, 1995; Zucker & Riordan, 1990) and that deaf children demonstrate weakness in this area (Bracken & Cato, 1986). In general, there is currently a lack of information available regarding the informal knowledge that young deaf children arrive at school with both overall and in terms of mathematics specifically.

In terms of language, as research by Mervis et al. (1994) cited in this chapter indicates, we know that young hearing children are able to demonstrate knowledge of hierarchical relationships among words. This ability was also evident in Mervis et al.'s (2003) discussion of Ari and the categories of words he used before the age of 2 years. Since classification studies done with deaf children have used concrete materials rather than language (Best, 1972, 1975;

Furth, 1961), it is not known what these language relationships look like for deaf children; however, since research evidence suggests a relationship between language and early mathematics concept development (Huttenlocher et al., 1994; Sophian & McCorgray, 1994), this is an additional area worthy of further investigation. In addition, more research is needed to examine young deaf children's concept development in general. Since classification skills are required to organize concepts and create schema (Mervis, 1994), and classification is also a critical part of early mathematics (Deak et al., 2002; Joint Position Statement of NAEYC and NCTM, 2002), it is possible that, given differences in language acquisition, deaf children's early concept development is another area to consider when looking for factors that contribute to the achievement gap. It is possible that, given language limitations, young deaf children are acquiring labels or concepts individually without learning the relationships among them. This may have an impact on further learning and concept development as complete schemas, or networks of related information, are not developing.

Furthermore, as theory and research discussed in this chapter indicate, the home environment is critical to later learning (Hart & Risley, 1995, 1999, 2003; Jimerson et al., 1999) and the quality of early learning experiences can influence the development of informal mathematics knowledge (Aubrey, et al., 2003; Phillips & Anderson, 1993; Saxe et al., 1987; Walkerdine, 1988). Since mediated learning experiences in particular provide a valuable context through which early learning is transmitted (Ben-Hur, 1998; Feuerstein, 1997; Klein, 2000, 1991; Schur et al., 2002) both in the classroom (Schur et al., 2002) and in the home (Klein, 2000, 1991), and no research data is currently available regarding the mediated learning experiences that young deaf children are exposed to in their home environment or how these experiences influence the informal knowledge they bring to formal schooling with them, including knowledge of basic concepts and early mathematics, this is an additional area where more research is critically needed.

As theory and research presented in this chapter indicate, it is possible that young deaf children are beginning formal schooling already at risk for low achievement in the area of mathematics. There is a need for research to determine if this is indeed the situation. The study discussed in this paper provides a glimpse into the early life experiences of young deaf children and addresses gaps in the literature regarding: the early mathematics knowledge of young deaf children and the types of experiences that lead to early mathematics competency; young deaf children's understanding of basic concepts; and the opportunities for mediated learning experiences existent in the homes of young deaf children.

Once an approximate age for the onset of the achievement gap is known, its cause can be identified and a plan can be generated to address this problem.

3.0 CHAPTER 3: METHODOLOGY

This study investigated the mathematics achievement of young deaf children (i.e., deaf children between the ages of 4 and 6 years) prior to formal schooling. The research included: examining how characteristics related to hearing loss and parents' education influenced young deaf children's mathematics achievement; investigating the role played by young deaf children's understanding of basic concepts, and exploring how effectively mediation techniques were used within the home environment.

In this chapter, the research design will first be described followed by a description of the data collection procedures, and the process of data analysis. Finally, strategies used to ensure credibility will be explained.

3.1 RESEARCH DESIGN

During the first level of this study the mathematics achievement of young deaf children (i.e., deaf children between the ages of 4 and 6 years) was examined in relation to the following background variables: etiology of hearing loss, age of onset, degree of hearing loss, use of assistive listening device, parents' hearing status, parents' level of education, participation in an early intervention program, and parents' signing skills. During the second level of the study, the mathematics achievement of young deaf children was examined in relation to: their understanding of basic concepts; and the mediation techniques used within their families. This examination was done by exploring the lives and backgrounds of a subgroup of six deaf children: three who demonstrated relative success in the area of mathematics achievement, as measured by mathematics ability score on the *Test of Early Mathematics Ability-3* (TEMA-3); and three who demonstrated relatively less success. Using mixed-methods research methodology, including aspects of a small N correlational study and multiple case-study design, the backgrounds of children in the "more successful" and "less successful" groups were critically examined in order to ascertain possible characteristics that contribute to mathematics achievement.

This section will include: a statement regarding the purpose of the study, the research questions, a depiction of the instruments used to answer the research questions, and a description of the rationale for the chosen methodology.

3.1.1 Purpose of the Study

The purpose of this study was to identify characteristics that are associated with more successful mathematics achievement in young deaf children. This study was guided by the research questions listed in the next section.

3.1.2 Research Questions

The following questions guided this study:

What factors are associated with mathematics achievement in young deaf children?

a. What is the relationship between level of mathematics achievement in young deaf children and characteristics related to hearing loss (i.e., etiology of hearing loss, age of onset/identification, degree of hearing loss, use of assistive listening device)?

b. What is the relationship between level of mathematics achievement in young deaf children and characteristics related to parents (i.e., parents' hearing status, parents' level of education, participation in an early-intervention program, parents' signing skills)?

c. To what extent do young deaf children with varying levels of achievement in mathematics understand basic concepts such as color, letter, numbers/counting, sizes, comparisons, shapes, direction/position, self-social awareness, texture/material, quantity, and time/sequence?

d. To what extent do varying levels of achievement in mathematics in young deaf children correspond with effective use of mediation techniques (i.e., intentionality/reciprocity, transcendence, and meaning) in their families?

3.1.3 Instruments

Data were collected for both levels of the study through the use of the instruments described below.

3.1.3.1 Background Questionnaire

The background questionnaire (see Appendix A) made use of closed and open-ended questions to obtain information regarding the nature of participants' hearing loss and specific family information. This information was used to examine the relationship between these background characteristics and each child's level of mathematics achievement, as measured by mathematics ability score on the TEMA-3 (i.e., to answer research questions 1a and 1b).

Questionnaires were sent home by administrators at each school. The questionnaires were completed by the parents or caregivers of participants and took approximately 15 minutes to complete.

While a limitation of the use of this instrument is that data were self-reported, this limitation is reduced by the fact that the majority of questions were not subjective in nature, (i.e., parents were asked to report child's age, level of hearing loss, etc.) On certain questions, that did require a subjective response (e.g., assessment of ones' own sign language competency), this limitation was reduced by accessing similar information through multiple questions (e.g., parents' signing skills were also accessed by answering a question regarding the quantity of sign language classes they had taken).

3.1.3.2 Test of Early Mathematical Ability

The Test of Early Mathematical Ability-3 (TEMA-3) (Ginsburg & Baroody, 2003) is a test that utilizes both informal and formal tasks to measure the mathematics ability of young children between the ages of 3.0 years and 8.11 years. The test takes approximately 40 minutes to administer and is given to each child individually. Test results are available as standard scores, percentile ranks, age, and grade equivalents.

The purpose in using this instrument was to provide the researcher with a standardized means of assessing the informal and formal mathematics ability of participating children in a variety of areas related to the understanding of number (i.e., number comparisons, calculation, numeral literacy, and number facts).

The TEMA-3 was standardized based on the responses of 1,219 children whose characteristics approximate those reported in 2001 U.S. census information. Internal consistency reliabilities for the TEMA-3 are reported to be above .92 (Ginsburg & Baroody, 2003). A prior version of the TEMA, TEMA-2, has been used in other research studies (Arnold, Fisher, Doctoroff & Dobbs, 2002; Teisl, Mazzocco & Myers, 2001) to assess young children's mathematical performance. One limitation of the use of this assessment tool is that it has not been normed for deaf children. Prior to the current study there was also no documented evidence of use of this test with deaf children. However, to evaluate the appropriateness of this instrument for deaf children, the researcher did experiment with the use of the test with one deaf child, within the age range of the sample chosen for this study, prior to selecting the instrument for use. Aside from administering the test using sign communication (for students who used this methodology of communication), no changes were made to administration of the test due to hearing loss.

The TEMA-3 was administered to participants individually by the researcher in a room within the school building free from distractions. When necessary to facilitate separation, an aide accompanied the child to the test area. The test was administered using the child's preferred language (i.e., ASL, spoken English with sign support, spoken English without sign support).

Test administration started for each child at the entry point suggested by the TEMA-3. For 4 year olds, the entry point was question number 7; for 5 year olds the entry point was question number 15; and for 6 year olds the entry point was question number 22. A basal score was achieved at the highest five consecutive items that the child answered correctly. If five items in a row were not answered correctly at the entry point, the test continued backward until a basal score was achieved. A ceiling score was reached when the child answered five consecutive items incorrectly.

3.1.3.3 Bracken Basic Concept Scale-Revised (BBCS-R)

The Bracken Basic Concept Scale-Revised (Bracken, 1998) is a test that uses formal tasks to measure the basic concept acquisition of young children between the ages of 2-6 years and 7-11 years. The test takes approximately 30 minutes to administer and is given to each child individually. Test results are available as standard scores, percentile ranks, and concept-age equivalents.

The purpose for using this test was to provide the researcher with a standardized means of assessing participants' understanding of basic concepts (i.e., color, letters, numbers/counting, sizes, comparisons, shapes, direction/position, self-social awareness, texture/material, quantity and time/sequence).

The test was standardized based on the responses of 1,100 children between the ages of 2-6 years and 8-0 years whose characteristics approximate those reported in 1995 U.S. Census information. The Bracken Basic Concept Scale (BBCS) has been used in other research studies to assess young children's understanding of basic concepts (Akman, Ipek & Uyanik, 2000; Bracken & Cato, 1986). A limitation of the use of this assessment tool for the current study is that it has not been normed for deaf children; however, the BBCS has been used in a previous study to assess the basic conceptual knowledge of deaf children (Bracken & Cato, 1986).

3.1.3.4 Parent Interview

An interview was conducted with parents of children participating in the second level of the study. This instrument (see Appendix B) utilized open-ended questions to obtain information regarding young deaf children's learning at home and their parents' perception of their role as their children's first teachers. Approximately 40 minutes was needed to conduct each interview. Parents of participating children were interviewed in person by the researcher in their home environment using the parents' primary language.

The purpose of the parent interview component was to collect detailed information regarding children's understanding of basic concepts and daily mediated learning experiences that occur within a naturalistic environment. The interview provided the researcher with access to parents' perceptions of their children's daily environments that would not have been available through observation alone.

A limitation of the use of this instrument is that it was subjective, requiring parents to offer opinions and responses to questions that they may or may not have been comfortable discussing with the researcher, an individual whom they had recently met. This limitation was reduced through use of triangulation and member checks. Data were collected using a variety of instruments, and transcripts from the interviews were shared with parents to check that their perspectives had been accurately recorded.

3.1.3.5 Parent Child Activity (PCA)

Parents of Level 2 participants were asked to conduct a mathematically-based activity, "This is In, This is Not," from the book Family Math for Young Children (Coates & Stenmark, 1997) with their deaf child. The educational purpose of the activity is to observe, describe, and sort into categories. The written description of the activity directs parents to collect a variety of items (i.e., toys, kitchen utensils, food products, etc.) to be used during the activity. Parents are then directed to designate a sorting space. The game takes place as parent and child take turns sorting items into the sorting space. The parent might begin, for example, by picking up a blue car and saying, “This is in (the sorting space) because it is blue.” According to activity directions, all items are sorted dichotomously as either belonging to a designated category, or not.

If parents wished, other children in the family were welcomed to participate in the activity. The activity was videotaped; however, in an effort to make the activity as “natural” as possible, the researcher left the room while the activity was being conducted. The time needed to conduct this activity ranged from 5 to 30 minutes depending on the family.

Depending on how it was mediated, this activity could address a variety of basic concepts, (e.g., size, direction/position, time, quantity, comparisons, texture/material, color, etc.). The purpose of this activity was to observe children’s understanding of basic concepts and parents’ use of mediation techniques while engaging in an activity with their deaf child that had the potential to develop mathematical ability.

A limitation of the use of this instrument is that it was a one-time event and may or may not have reflected “typical” parent-child interaction. In addition, the activity was videotaped which may have influenced the “naturalness” of the interaction recorded. This limitation was reduced through the use of triangulation and member checks. Data were collected through a variety of sources and the transcript from the event was shared with parents to check that they were comfortable with the information recorded.

3.1.3.6 Researcher-Child Activity (RCA)

The researcher conducted a mathematically-based activity, “My Rule, Your Rule,” from the book Family Math for Young Children (Coates & Stenmark, 1997) with each Level 2 participant.

Similar to the PCA, the educational purpose of the activity was to observe, describe, and sort into categories. The written description of the activity directs adults to collect a variety of small items for sorting (i.e., buttons, small toys, picture cards, play money, keys, bottle caps, seashells, etc.) to be used during the activity. Adults are then directed to designate sorting spaces. The game takes place as adult and child take turns sorting items into the sorting space then asking their partner to figure out the rule that was used to create the sort. For example, the adult might begin by putting a variety of "blue" things together then say, "I'm thinking of a rule. Try to read my mind as I put something else in the sorting space that matches my rule. What do you think my rule is?"

Approximately 30 minutes were needed to conduct this activity with each child. The instrument was administered to each child individually within the school setting and was videotaped.

This activity was chosen because it is an extension of the activity chosen for the PCA. As conducted, this activity incorporated opportunities for children to demonstrate their understanding of the following basic concepts: size, direction/position, time, quantity, comparisons, texture/material, and color. The purpose of this activity was to informally assess participants' understanding of basic concepts.

A limitation of use of this instrument was that it recorded only one activity and may not have captured "typical" performance. This limitation was reduced through the use of triangulation. Data were collected using a variety of instruments.

3.1.3.7 Full-Day Observation (FDO)

The researcher spent one full weekend day (i.e., Saturday or Sunday, approximately from breakfast to bedtime) with each Level 2 participant and his/her family. Data were collected via two types of field notes. First, a checklist following the format in Appendix E was kept to record the deaf child's activity every 10 minutes including with whom s/he was interacting and the type of activity in which s/he was engaged. Second, field notes were used to record observations of adult-child interaction.

The researcher arrived at each participant's home at approximately the time the child woke up and stayed until approximately bedtime; therefore, approximately 12 hours were needed to administer this instrument. The researcher observed the child and his/her family interaction during the entire day, to the greatest extent possible, remaining a non-participant observer.

The purpose of this instrument was to observe typical interaction between the participant and his/her parents/family members in order to understand and describe the mediation techniques used by adult family members in their interactions with young deaf children. This instrument also allowed the researcher to record evidence of children's use of basic concepts as observed in a naturalistic environment.

A limitation of this instrument is that only one day was observed, therefore "typical" behavior may or may not have been captured. In addition, the researcher's presence in the home may have influenced the naturalness of behavior observed. This limitation was reduced through use of triangulation and member checks. Data were collected using a variety of instruments and the researcher's notes were shared with the families to check that they were comfortable with the information captured.

3.1.3.8 Researcher as an Instrument

Since the design of this study incorporated the use of qualitative data, it is important to note the role of the researcher as an instrument for data collection. The researcher was the lens through which all study-data were viewed; she decided: what questions to ask; what to observe; and ultimately, what was meaningful enough to record (Mertens, 1998).

The researcher in this study was a doctoral student at the University of Pittsburgh. She was a hearing, bilingual individual with native proficiency in the English language and additional proficiency in American Sign Language (ASL), with over 10 years of signing experience. She had over six years of experience as a teacher of deaf students from the preschool through the upper elementary grade levels, and additional experience as an early-intervention specialist for families with young children (i.e., birth to age three years) with a newly discovered hearing loss.

During Level 2 of this study, when the researcher entered the homes of the families of participants for data collection, she was conscious of her need to adapt to the culture present within each family environment. A variety of measures were taken to enhance trust including: initiating communication with each family through use of an on-site school administrator whom the families knew and trusted; meeting with the family prior to the day of full observation, to discuss the purpose of the study and explain what she would be doing during the day of observation; and using the dominant language/communication methodology present in the home (i.e., ASL, spoken English, spoken English with sign-support). In summary, the researcher was cognizant of the need to present herself as someone interested in learning about the lives of young deaf children and their families, rather than as an "expert" in the field.

A limitation of the role of the researcher as an instrument is that information was captured through the perspective of only one individual who brings her own biases to the task of observation. This limitation was reduced through the use of triangulation and member checks. Data were collected using a variety of instruments. In addition, transcripts were shared with families to ensure that information recorded accurately captured their perspective of events that transpired during the day of observation, and that parents were comfortable with information recorded.

3.1.4 Rationale for Methodology

Mixed-methods research methodology was determined to be the most appropriate design to achieve the purposes of this study; specifically, elements of a small N correlational study, and multiple case-study design were used.

Using quantitative measurement, two standardized tests were used for data collection, the Test of Early Mathematics Ability-3 and the Bracken Basic Concepts Scale-Revised. A benefit to using standardized tests is that administration and scoring of the test is uniform (Mertens, 1998). In addition, norm-referenced standardized tests, such as the TEMA-3 and the BBCS-R, include percentile ranks describing students within a particular norming group who received the same score. These normed scores can be used to compare individuals taking the test to the established norms (Mertens, 1998). A concern with the use of norm-referenced tests, however, is that they may be biased against populations that do not match the established characteristics of the "norm", for example, children with a low-incidence disability such as deafness. For this reason, the scores of norm-referenced standardized tests should not be used in isolation to make determinations or generalizations regarding the performance of populations who do not completely match the characteristics of the "norm" group (Mertens, 1998). One way in which additional information can be obtained regarding individuals outside of the "norm" is through qualitative methodology.

Since qualitative research is typically used in research projects that seek to examine a program, setting, or problem in detail and in its natural setting (Creswell, 1998; Mertens, 1998), it is particularly well-suited to this study. Qualitative research may be chosen due to the nature of the research questions examined by the study or to add depth to a quantitative study. Qualitative research is particularly applicable when only small sample sizes are available and there is high variability within the population (Mertens, 1998). This is the case when the sample consists of individuals from a low-incidence disability population such as deaf children.

One form of qualitative research is the case-study approach. Case-study research involves the detailed description of a particular, or multiple, cases (Creswell, 1998). An *explanatory* case study seeks to examine the cause for a particular occurrence; this approach is particularly useful when the research question asked is "how" or "why" a particular event occurs (Yin, 2003).

Case studies have been used effectively in mathematics research to examine young children's learning of mathematics. A multiple case-study approach was used by Aubrey, Bottle and Godfrey (2003) to examine preschoolers' learning of early mathematics both in the home and outside of it. A case study about a toddler named Blake was conducted by Benson and Baroody (2002) in order to critically examine the young child's development of number understanding. A study by Phillips and Anderson (1993) used a case-study approach to examine how one mother's interactions with her preschool-age daughter influenced the child's mathematics learning. Another example is Leder (1992) who used a multiple case-study approach to examine the mathematics learned before formal schooling by two preschool-age boys in Melbourne, Australia.

Case studies have also been used effectively to examine the experiences of deaf children. An ethnographic case study was conducted by Blackburn (1999) in order to critically examine the interaction between a deaf child and his hearing family members. A case study was also conducted by Evans (1998, 1995, 1994) to examine the communicative experiences and pragmatics development of a deaf girl within her hearing family.

The current research study uses a multiple case-study design to examine factors associated with young deaf children's demonstrated mathematics ability. The hypothesis examined is that deaf children's understanding of basic concepts, their interactions with their families, and the opportunities for mathematics learning within the home that young deaf children have access to, are critical factors contributing to mathematics achievement. The essence of such factors can most effectively be observed if considered as naturalistic data and analyzed using a qualitative approach, such as multiple case studies.

3.1.5 Section Summary

As described in the preceding section, this study utilized a mixed-methods design to critically analyze the mathematics achievement of young deaf children, and factors that might contribute to that achievement. Quantitative and qualitative instrumentation was used during this study; specific information regarding data collection procedures will be described in the section that follows.

3.2 DATA COLLECTION

3.2.1 Population

Deaf children between the ages of 4 and 6 years, but not yet in first grade, with no additional disabilities, and from homes in which either American Sign Language or spoken English was the primary language, participated in this study. This age level was chosen in order to examine deaf children's mathematics knowledge prior to formal mathematics instruction.

3.2.2 Selection of Participants

Consent to participate in this study was received from the families of 30 deaf students between the ages of 4 and 6 years. Consent packets were sent home to parents of all eligible students by school administrators. All students meeting the critieria (i.e., deaf children, between the ages of 4 and 6 years but not yet in first grade, with no additional disabilities, and from homes in which either American Sign Language or spoken English was the primary language spoken), were invited to participate in the study. However, due to illness on the day of data collection, one child was unable to participate. The final sample, therefore, consisted of 29 children from 7 schools for the deaf. The ages of the children were as follows: 8 children were 4 years old; 19 children were 5 years old; and 2 children were 6 years old. Seventeen of the children had at least one deaf parent, 12 children had hearing parents.

During Level 1 of the study, a background questionnaire (Appendix A) was completed by an adult family member of each participant and the TEMA-3 was administered to all 29 participants individually. The scores of the TEMA-3 were then used to select participants for

Level 2 of the study. Participants for Level 2 were selected as follows: Scores within one standard deviation of the mean formed the "average" group; scores two standard deviations above and below the mean formed the "more successful" and "less successful" groups respectively. The ages of the 6 participants in the "more successful" group ranged from 4.6 years – 5.11 years with a mean age of 5.3 years. Five of these children had at least one deaf parent, 1 had hearing parents. The ages of the 7 children in the "less successful" group ranged from 4.10 years to 5.9 years with a mean age of 5.3 years. Two of these children had at least one deaf parent, 5 had hearing parents.

Three participants from each group were randomly selected from each group (i.e., the "more successful" and "less successful" groups) and invited to participate in Level 2 of the study. Collectively, each group of participants is described below.

Children in the "more successful" group ranged in age from 4 years-8 months to 5 years-10 months. All three had at least one sibling and were the oldest children in their families. All three children had deaf parents and American Sign Language was the language of the home. All three children lived in rural to semi-rural areas.

Children in the "less successful" group ranged in age from 5 years-9 months to 5 years-11 months. One child had two younger siblings. The other two were the only children in the family. All three children had hearing parents and spoken English, with some sign support, was the language of the home. One child had a cochlear implant. One child lived on a farm, another lived in a semi-rural area, and the third lived in an apartment in an urban area.

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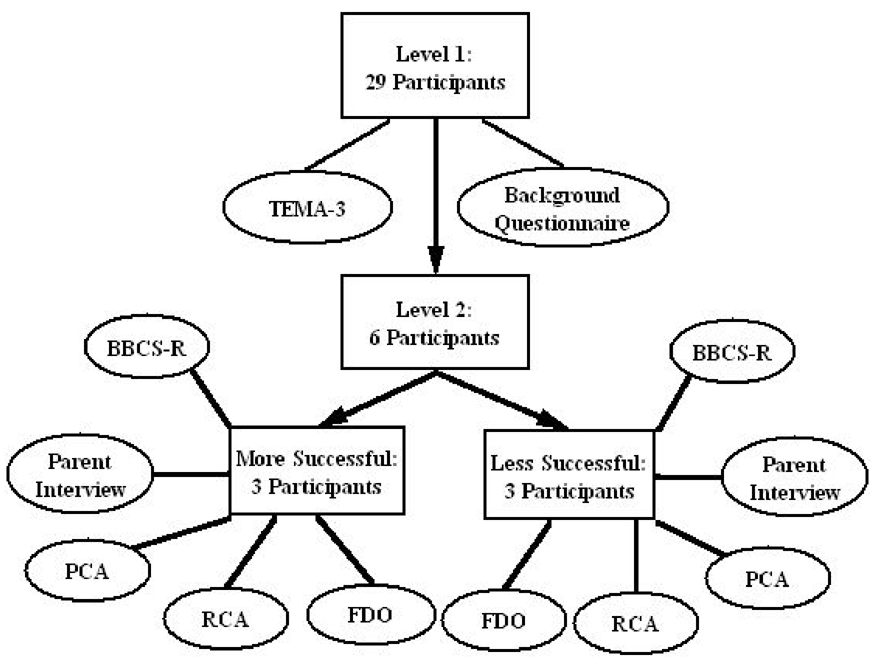
3.2.3 Order of Data Collection

The flowchart in Figure 3-1 demonstrates how instruments were used for data collection during this study. The background questionnaire and TEMA-3 were administered to all Level 1 participants. Only Level 2 participants took part in the remaining instruments (i.e., BBCS-R, Parent Interview, Parent-Child Activity, Researcher-Child Activity, and the Full-Day Observation).

Figure 3-1: Data Collection Flowchart



3.2.4 Section Summary

As described in this section, data were collected in a variety of ways during this study. During Level 1, data were collected from 29 participants in the form of performance on a test of mathematics ability and background information from a questionnaire. During Level 2, more detailed data were collected from 6 participants in the form of a test to assess knowledge of basic concepts, a parent interview, a parent-child activity, a researcher-child activity, and a day of full observation. In the next section, more detailed information will be provided regarding how the data were coded and analyzed.

3.3 DATA ANALYSIS

3.3.1 Data Coding and Analysis

Quantitative data collected during this study were entered into an SPSS database. Due to small sample size, nonparametric statistics were initially performed using the Mann-Whitney Test to test for differences between two independent categorical variables on a continuous independent variable (test score) and the Kruskal-Wallis Test to test for differences among three or more independent categorical variables on a continuous independent variable (test score). The more powerful parametric alternatives of these statistical techniques however, an independent-samples t-test and one-way between groups analysis of variance (ANOVA) respectively, were found to yield the same results and are, therefore, the statistics reported in the sections that follow. Given the small sample size for this study (Level 1, $\underline{n}$=28; Level 2, $\underline{n}$=6), a large contrast between groups was required for the difference to be significant. For this reason, statistical findings must be accepted with caution.

Qualitative data collected during this study were used to answer the final two research questions; the first question was based on deaf children's understanding of basic concepts, the second was based on mediation techniques used by families when interacting with their children. Two coding schemes were developed: the basic concepts coding scheme is found in Appendix C; the mediation techniques coding scheme is found in Appendix D. These coding schemes are described in more detail below.

When using qualitative data, coding is seen as a major component of the analysis (Miles & Huberman, 1994). Coding occurs as tags or labels are used to assign meaning to information that is collected during the study. An effective strategy to use in code generation is to begin with a "start list" based on the research questions that guide the study (Miles & Huberman, 1994). As it is used to go through the data, this "start list" is revised and a coding scheme develops.

Videotapes from the Parent Interview, Parent-Child Activity, and Researcher-Child Activity were transcribed into transcript form. Field-notes from the Full-Day Observations were also transcribed and turned into transcripts. All four transcripts were combined and merged into a "complete" transcript. The complete transcripts were then coded according to the coding schemes.

3.3.1.1 Coding for Understanding of Basic Concepts

In order to assess participants' knowledge of basic concepts in a non-test situation (i.e., beyond the BBCS-R), 3 instruments were used for data collection: a structured Parent-Child Activity (PCA); a structured Researcher-Child Activity (RCA); and a Full-Day Observation (FDO). The PCA and the RCA were designed specifically to access young children's knowledge of basic concepts through the use of classification activities. The FDO provided the researcher with the opportunity to observe the child's use of basic-concept information in a naturalistic environment.

The rationale for the use of tools to observe children's use of basic concepts in a naturalistic environment was that, since the BBCS-R is a language-based test, it is possible that children might demonstrate concrete use of basic concepts in real-world contexts, with or without the use of language, thereby indicating that young deaf children have greater awareness of basic concepts than what they are able to demonstrate in a test situation. For this reason, it was necessary to rename the concepts examined during the BBCS-R in order to consider them within a larger context (See Basic Concepts Coding Scheme, Appendix C). As indicated in Table 3-1, concepts from the BBCS-R were viewed as embedded within the concept strands of the Basic Concepts Coding Scheme as described below.

Table 3-1: Basic Concepts Correspondence Codes

Basic Concepts Coding Scheme	***Bracken Basic Concept Scale (Matching Concepts)***
Number and Operations	Number, Counting, Quantity
Geometry and Spatial Sense	Shape, Direction/Position
Measurement	Size, Time
Algebraic Thinking	Comparisons, Color, Texture/Material
Problem Solving	None
Personal Awareness	Self Awareness
Social Awareness	Social Awareness
Early Literacy	Letters

The BBCS-R concepts of “Number”, “Counting”, and “Quantity” require students to point to pictures representing specific numeric quantities (e.g., “nine bumblebees”), for the “Number” and ”Counting” subcomponents, and non-numeric quantities (e.g., the tree with “*many* apples”) for the “Quantity” subcomponent. These concepts were viewed as embedded within a *Number and Operations* strand of concepts in the coding scheme created for Level 2 of this study. The *Number and Operations* strand included: counting; labeling numbers in the environment; using numbers to determine quantity; making use of one-to-one correspondence;

using mathematical language to express quantitative relationships and compare groups; and using ordinal number words accurately.

The BBCS-R concepts of “Shape”, and “Direction/Position” require students to point to pictures representing specific shapes (e.g., “circle”) for the “Shape” component, and spatial orientations (e.g., “behind”) for the “Direction/Position” component. These concepts were viewed as embedded within a *Geometry and Spatial Sense* strand of concepts in the coding scheme created for Level 2 of this study. The *Geometry and Spatial Sense* strand included: labeling shapes in the environment; putting shapes together to create pictures (including puzzles); and using language receptively and/or expressively to describe spatial locations.

The BBCS-R concepts of “Size” and “Time” require students to point to pictures representing specific sizes (e.g., “big”), and times/sequences (e.g., “night”; the picture in which the “person is *leaving* the store”). These concepts were viewed as embedded within a *Measurement* strand of concepts in the coding scheme created for Level 2 of this study. The *Measurement* strand included using language receptively and/or expressively to demonstrate awareness of measurement concepts such as time/sequence, distance, size, amount, speed, and/or weight.

The BBCS-R concepts of “Comparisons”, “Color”, and “Texture/Material” require students to point to pictures that: make comparisons (e.g., “which boxes are *not the same*”); identify colors (e.g., “black”); and identify texture/material (e.g., “which one is *heavy*”). Within a naturalistic environment, the ability to label attributes, such as color or texture, is required in order to isolate a category by which items can be grouped or classified. An ability to sort, categorize, and classify items by their attributes is recognized by the State of Pennsylvania Logical Mathematics Early Learning Standards for Pre-Kindergarten (2005) as part of the standard “understand patterns, relations and functions”. For purposes of this study, concepts requiring labeling attributes and making comparisons were viewed as embedded within the context of algebraic thinking. The strand of concepts related to *Algebraic Thinking* included: demonstrating understanding of relationships involving identifying attributes, making comparisons, and/or classifying; explaining why/how things are organized; and recognizing/extending patterns.

The BBCS-R concept of “Self/Social Awareness” requires students to identify pictures in which a specific feeling is being conveyed (e.g., “which person is *angry?*”). For purposes of this study, this concept was viewed as embedded within two separate strands of concepts related to *Personal Awareness* and *Social Awareness*. Concepts related to *Personal Awareness* included: awareness of self, indicated by an ability to describe ones’ self and communicate ones’ likes, dislikes, wants, needs, thoughts, and feelings; demonstrated independence, indicated by choosing ones’ own activities and self-reliance in self-care activities; demonstrated pride in ones’ own accomplishments; demonstrated ability to understand the consequences for ones’ own behavior; an ability to follow rules and directions; putting materials away independently; and demonstrated recognition of situations that are not safe. Concepts related to *Social Awareness* included: interacting appropriately with others; initiating and/or playing games; taking turns; sharing; engaging in playful teasing; demonstrating compassion by responding empathetically to others who appear upset or in need; making requests appropriately, seeking help when needed; offering help and/or advice; recognizing and respecting the feelings, rights and belongings of others; demonstrating curiosity and seeking information; and asking the opinion of others.

The BBCS-R concept of “Letters” requires students to identify/label various letters (e.g., “A”). As part of a naturalistic environment, this subcomponent was viewed as embedded within the context of *Early Literacy* which includes the child's attempt to spell words, and interact with books and print.

In addition, the strand of "Problem Solving" was added to the coding scheme used in the present study. The "Problem Solving" strand included: gathering information needed to solve a problem; using strategies to solve a problem; and telling others how to solve a problem.

All videotaped data were transcribed and merged with notes from the FDO. The product, a complete transcript, was then analyzed using the Basic Concepts Coding Scheme. Specific transcript data that held evidence of knowledge of basics concepts (as defined by the Basic Concepts Coding Scheme), were recorded as an "episodes." The definition of an "episode" is a piece of data that demonstrates an understanding of one or more of the basic concepts described in the Basic Concepts Coding Scheme. Individual episodes may have been coded for more than one basic concept. Episodes also varied in length from <u>one line</u> (for example, a note recording that a child separated clean and dirty laundry indicating the ability to make comparisons [part of the *Algebraic Thinking* strand]), to <u>multiple pages</u> (for example, 5 pages describing the PCA in which the child demonstrated appropriate interaction with others [part of the *Social Awareness* strand]). Although an attempt was made to code all episodes demonstrating knowledge of basic concepts evidenced by children, it should also be noted that this was inferential coding and therefore did not need to be exhaustive (Miles & Huberman, 1994). The primary focus of this coding was to find what Miles and Huberman refer to as "good explanatory exemplars (p. 65, 1994)."

In addition, some measures were coded with the child as the unit of analysis (e.g., child playing independently during the FDO) and other measures were coded with the adult-child dyad as the unit of analysis (e.g., child and adult playing interactively during the PCA), yet both were put into the same category. Recognizing that this is difficult to disentangle and, as such, is a limitation of the study, the researcher acknowledges that the child's understanding of basic concepts was being analyzed, not the measure through which that knowledge was demonstrated. To access what young children know, the researcher recognized that interaction with others was essential. For this reason, multiple instruments were used to collect data regarding participants' knowledge of basic concepts.

3.3.1.2 Coding for Use of Mediation Techniques

In order for mediation to occur, there must be interaction between the mediator and the child (Feuerstein, 1997). For this reason, lines within the complete transcripts that did not describe interaction between adults and children were removed. The remaining data were divided into "events." The definition of an event is a portion of a complete transcript that corresponds to a period of interaction and/or dialogue between adults and children. Each transcript was divided into "events" before being coded for occurrence of use of mediation techniques. An "event" may have included one or more "occurrence" of mediation.

The coding scheme in Appendix D was used to code events for occurrences of mediation. Feuerstein (Sharron, 1987, as cited in Sharron, 1994) warned against over-operationalizing the components of the mediated learning experience (MLE) as the criteria were not designed to be used as "a set of simple behavioristic recipes," and as over-operationalization is likely to distract from the richness and essence of each dimension (i.e., *Intentionality/Reciprocity*, *Transcendence*, *Meaning*). Keeping this in mind, a "critical feature" is marked on each of the three dimensions described in the coding scheme. To examine use of *Intentionality/Reciprocity*, the learning environment was analyzed; to examine *Transcendence*, the explanations parents offered were analyzed; and to examine *Meaning*, the questions that parents asked were analyzed. The specific nature of how each dimension of mediation (*Intentionality/Reciprocity, Transcendence, Meaning*) was coded in this study is described in more detail below.

The first dimension of mediation, *Intentionality/Reciprocity* refers to the manner in which a mediator sets up a learning experience. An effective mediator will monitor the environment or learning situation in a manner so as to concretely maximize learning (Feuerstein, 1997). The critical feature of the *Intentionality/Reciprocity* dimension is an environment that maximizes learning. As described in the coding sheet in Appendix D, adults may maximize learning for their children by: establishing learning opportunities in which children can develop independence and self-sufficiency; acting in a way to consciously modify children's behavior; making conscious use of materials and/or environmental tools to enhance children's learning and cultural understanding; initiating conversations that are appealing to young children; initiating learning activities, events, and experiences that anticipate learning; establishing schedules and routines that communicate information regarding family beliefs, rules, traditions, and values; communicating the expectation that children will learn cultural values, appropriate behavior, and use of social mores; being responsive to child's lead during interaction; soliciting child's involvement in activities and conversations; and/or expressing interest and pride in children's accomplishments.

The second dimension of mediation, *Transcendence,* refers to the potential for the current learning experience to go beyond the immediate situation. The effective mediator will provide information explaining why an event occurs or why a particular experience is necessary. The critical feature of *Transcendence* is the explanations that mediators offer. Occurrences coded for *Transcendence* during this study included explanations that: placed actions or events within a larger context and/or established causal relationships between events; made references to and/or established a connection between past, present, and future events for children; and/or encouraged children's developing awareness of self and others by encouraging independence, decision-making, and the acceptance of responsibility.

The third dimension of mediation examined during this study was *Meaning*. Effective mediators will encourage children to apply their concepts or ideas to their observations. The critical feature of this dimension is the questions mediators ask to stimulate children's thinking. Occurrences coded for *Meaning* during this study included questions that encouraged children: to solve problems; answer questions; use logical thinking; refer to past experience; and/or project into an abstract future event, thereby encouraging children to apply their knowledge of the world to explain why things happen the way they do.

The three dimensions of mediation are interdependently related with the deepest layer, *Meaning*, including characteristics of the other two. Since it is difficult to consider each dimension exclusively, for the purpose of coding, each dimension was examined according to its critical feature: the environment for *Intentionality/Reciprocity*; explanations for *Transcendence*, and questions asked for *Meaning*.

3.3.2 Section summary

As described in this section, data were analyzed both quanitatively and qualitatively during this study. Statistics, in the form of independent-samples t-tests and ANOVAs were done to compare differences between children who demonstrated "more" and "less" success in the area of mathematics in relation to background characteristics and knowledge of basic concepts. More information regarding the children and their experiences was then obtained through the qualitative coding and analysis of data collected during this study. The next section describes efforts that were taken to ensure that credibility was maintained as data collected from this study were analyzed.

3.4 CREDIBILITY

According to Guba and Lincoln (1989), credibility in qualitative research is the equivalent of internal validity in quantitative research. Credibility involves determining if there is a true relationship between the constructs explored by the study. In this study this meant determining: 1) if there was a true relationship between deaf children's understanding of basic concepts and their mathematics ability; 2) and determining if there was a relationship between mediation techniques used by parents and deaf children's mathematics ability.

To establish credibility for data collected during the second level of this study, a variety of "checks" were in place. These checks took the form of triangulation, member-checks, and peer code-checking.

3.4.1 Triangulation

The purpose of triangulation is to establish that data that were collected from a variety of sources consistently relay the same findings (Mertens, 1998). Multiple instruments were used for data collection during this study including the use of objective assessment tools (e.g., TEMA-3, BBCS-R), interviews with parents, and observations. As will be discussed in subsequent chapters, findings were consistent across data sources.

3.4.2 Member Checks

Member checks are viewed as the most important aspect of establishing credibility in qualitative research (Mertens, 1998). The purpose of member checks is to ensure that the perspectives and viewpoints of participants are being accurately recorded. When videotapes from the parent interview, parent-child activity, and field-notes from the full-day observation had been transcribed, a complete transcript packet, that did not include the researcher's interpretations, was shared with parents of participants to verify that individuals' intentions and/or perspectives had been accurately captured. Four families signed and returned the transcripts by mail indicating their agreement. The remaining two families were contacted by phone. They also indicated their agreement with the information recorded.

3.4.3 Reliability

According to Wiersma (2000), research reliability refers to the consistency of research methodology. Reliability was measured in two ways during this study. First, since the language used in the majority of videotaped data was American Sign Language, 25% of each videotape was reviewed to ensure that transcriptions were accurately recorded into English. The reviewer was a deaf faculty member and instructor of American Sign Language in the department of linguistics at a university. All transcripts were found to be accurately recorded.

Second, a peer in the field of deaf education was solicited to perform a reliability-check on data that were coded for Basic Concepts and Mediation Techniques. Miles and Huberman (1994) refer to the benefits of check-coding for two reasons: first, to clarify definition meaning, thereby ensuring that individual biases are not contributing to definition interpretation; and second, as a reliability check. For the basic concepts data, percent agreement was found using the following formula:

Reliability = Number of agreements / Total number of agreements + disagreements.

Inter-rater reliability for the mediation data was measured using Cohen's Kappa. This statistic tends to provide a stronger measure of reliability as it accounts for the possibility that agreement could have occurred by chance (Cohen, 1960); however, it can only be used when the categories used for coding are nominal, independent, mutually exclusive, and exhaustive (Cohen, 1960). Because the basic concepts data was not mutually exclusive or exhaustive in form, Cohen's Kappa could not be used to measure inter-rater reliability. The coding scheme and data set used for the mediation data complied with the specifications for Cohen's Kappa, thereby making it an appropriate statistic to use as a measure with these data. Kappa scores can range from 0-1.00. Larger values indicate better reliability, with a Kappa score of greater than .70 considered acceptable (Index of inter-rater reliability, n.d, online source).

Of the six complete transcripts that provided the data for the second level of this study, a stratified random sample was selected for review. Two transcripts (i.e., one transcript from the "more successful" group and one transcript from the "less successful" group) were reviewed for the basic concepts data; two different transcripts (i.e., one transcript from the "more successful" group and one transcript from the "less successful" group) were reviewed for the mediation data.

For the basic concepts data, inter-rater reliability was found using percent agreement on data from one child in each group (i.e., "more successful" and "less successful"). Percent agreement scores from each child were averaged to create the inter-rater reliability mean scores. As reported in Table 3-2, percent agreement, per concept, had a rating of 93% or greater.

Table 3-2: Basic Concepts Inter-Rater Reliability, Percent Agreement

Basic Concept	Inter-rater Reliability Mean Score
Number and Operation	93%
Geometry	95%
Measurement	93%
Algebra	96%
Problem Solving	95%
Personal Awareness	97%
Social Awareness	98%
Early Literacy	97%
Overall coding system	96%

For the mediation data, Cohen's Kappa was used to check for inter-rater reliability. As reported in Table 3-3, inter-rater reliability was at a level of .771 or higher across all categories.

Table 3-3: Mediation Inter-rater reliability, Cohen's Kappa

Mediation	More Successful	Less Successful
None	.771	.892
Intentionality/Reciprocity	.840	.842
Transcendence	.910	.939
Meaning	.901	1.0
Overall coding system	.855	.903

3.4.4 Section summary

As described in this section, a variety of approaches were used to ensure credibility of data analysis. Triangulation was used as data were collected from a variety of sources, member checks were used to ensure family agreement with data recorded during observations, and reliability checks were included to maintain that information coded in the written transcripts was reliably coded.

3.5 CHAPTER SUMMARY

In summary, as described in this chapter, the purpose of this study was to investigate factors associated with the mathematics achievement of young deaf children, as measured by mathematics ability scores on the TEMA-3. The deaf children in this study were between the ages of 4 and 6 years, but not yet in first grade, with no additional disabilities, and from homes in which either American Sign Language or spoken English was the primary language. There were two levels to the study. During Level 1, quantitative data were collected through use of a background questionnaire and a standardized test assessing mathematics ability (i.e., TEMA-3). Three children who were relatively "more successful" and 3 children who were relatively "less successful" were then randomly selected to participate in Level 2 of this study. Data for Level 2 were collected using qualitative instrumentation and were analyzed for children's understanding of basic concepts and the mediation techniques used by families.

4.0 CHAPTER 4: RESULTS

This chapter will describe the results from the present study in the following way: first, results related to participants' mathematical ability, as demonstrated by their performance on the *Test of Early Mathematical Ability* (TEMA-3), will be discussed. Then, results will be presented to answer the first two research questions regarding: the relationships present between mathematics achievement, as measured by mathematical ability score on the TEMA-3, and characteristics related to the child and his/her hearing loss (research question 1); and characteristics related to parents (research question 2). Next, results will be presented to answer the third research question regarding participants' understanding of basic concepts. Finally, results will be presented to answer the fourth research question regarding the use of mediation techniques demonstrated in the homes of young deaf children.

4.1 MATHEMATICAL ABILITY

This section describes participants' mathematical ability as demonstrated by their performance on the TEMA-3. First, participants' scores will be discussed in relationship to TEMA-3 norms. Then, test items that appeared to be the most and least difficult for children, as demonstrated by performance on the TEMA-3, will be described. Next, results will be presented to answer the first two research questions. The relationship between characteristics related to children/hearing loss (i.e., etiology of hearing loss, age of onset, degree of hearing loss, use of assistive listening device) and mathematics achievement, as reported by mathematical ability score on the TEMA-3, will be reported (research question 1). Then, results related to the relationship between parent characteristics (i.e., hearing status, parents' level of education, participation in a parent-infant program, parents' signing skills) and participants' mathematics achievement, as measured by mathematical ability score on the TEMA-3, will be presented (research question 2).

The TEMA-3 was administered to all 29 children who participated in Level 1 of this study. Participants' ages were as follows: 27.6% (n = 8) were 4 years old; 65.5% (n = 19) were 5 years old; and 6.9% (n = 2) were 6 years old. The majority of children came from homes with at least one deaf parent: 59.6% (n = 17); 41.4% (n = 12) had hearing parents.

As indicated in Table 4-1, the TEMA-3 has established categorical score ratings to describe mathematical ability as follows: below 69 is "very poor"; 70-79 is "poor"; 80-89 is "below average"; 90-110 is "average"; 111-120 is "above average"; 121-130 is "superior"; and greater than 131 is "very superior" (Ginsburg & Baroody, 2003). Using the TEMA-3 ranking system, only one participant in this study scored above "average." Since this score (130) was more than 2 standard deviations above the group mean of the given sample (89.69), and more than one standard deviation away from the next highest score (109), it was determined to be an outlier and removed from the group considered for analysis. Remaining participants were ranked as follows: 13 participants scored in the "average" range; 7 participants scored in the "below average" range; 7 participants scored in the "poor" range; and 1 participant scored in the "very poor" range.

Table 4-1: TEMA-3 Score Distribution and Ranking

TEMA-3 Score	*Tema Rank*	*Number of Participants (n=29)*
>131	Very Superior	1 (outlier, removed from analysis)
121-130	Superior	0
111-120	Above Average	0
90-110	Average	13
80-89	Below Average	7
70-79	Poor	7
<69	Very Poor	1

One purpose of this study was to explore differences in the lives and experiences of young deaf children who were "more" and "less" successful in terms of mathematics achievement, even before the onset of formal mathematics education. Given the depressed distribution of scores on the TEMA-3 obtained from this sample, "more" and "less" could not be determined using the norming scale established by the TEMA-3 as only one child scored above average. For this reason, a different ranking system was used to categorize participants in this study based on the test scores obtained from the sample under consideration.

After removal of the outlier, participants were ranked into one of three groups as follows: participants with scores within one standard deviation (12.444) of the recalculated mean (88.25) formed the middle, or average group. Scores within two standard deviations above (>101) and below (<76) the mean formed the "more successful" and "less successful" groups, respectively.

As described in Table 4-2, using this ranking system participants were categorized as follows: 6 participants received scores in the "more successful" range; 15 participants received scores in the "average" range; and 7 received scores in the "less successful" range.

Table 4-2: TEMA-3 Adapted ranking

TEMA-3 Scores	*TEMA Rank*	*Number of Participants (n=28)*
>101 (102-109)	More successful	6
76-101 (79-100)	Average	15
<76 (68-75)	Less successful	7

The TEMA-3 includes a total of 72 test items, all participants in this study reached ceiling at or before test item number 37. A one-way between-groups analysis of variance was conducted to explore the raw scores (number of test items answered correctly) on the TEMA-3 for children in each of the three groups (more successful; average; less successful). There was a statistically significant difference at the .05 alpha level in raw score for the three groups (F=16.757, p=.000). Post-hoc comparisons using the Tukey HSD test indicated that the mean raw score for children in the "more successful" group (*M*=26.83, *SD*=5.913) was significantly different from children in the "average" group (*M*=16.27, *SD*=6.745) and children in the "less successful" group (*M*=8.00, *SD*=2.708). The raw score for children in the "average" group was also significantly different from children in the "less successful" group. Overall, children in the "more successful" group answered more questions successfully than children in either of the other two groups.

4.1.1 Challenge Level of Test Items

In order to evaluate the particular areas of early mathematics that were difficult for the children in this study, the challenge level of each test item was evaluated. This was essential in order to isolate the specific aspects of early mathematics that are difficult for young deaf children. The challenge level of each test item was determined based on the percentage of children answering an item correctly. Nine problems were answered correctly by 75% or more of the participants (i.e., 21 children or more). These items will be discussed in the next section as the "least challenging" test items. Seventeen test items were answered correctly by 25% or fewer of the participants (i.e., 7 children or fewer). These items will be discussed in a later section as the "most challenging" test items.

4.1.1.1 Less Challenging Test Items

The nine test items presented in Table 4-3 were solved correctly by 75% or more of participants ($\underline{n} \geq 21$) and are, therefore, considered the least challenging test items. Children in the "more successful" group answered all nine test items correctly however, of the total number of participants ($\underline{n}$=28), 14 participants answered at least one of these nine test items incorrectly. Of the children who answered these items incorrectly, seven participants received TEMA-3 scores that ranked in the "average" range and seven received scores that ranked in the "less successful" range. Four of the 14 children had at least one deaf parent; the remaining 10 had hearing parents.

These 14 participants varied in age as follows: 3 were 4 years old; and 11 were 5 years old. The three 4-year-olds each answered 3 or 4 of the 9 test items incorrectly. The 5-year-olds each answered between 1 and 6 of the 9 test items incorrectly.

In Table 4-3, the less challenging test items are arranged in order of difficulty with the least challenging test items appearing at the top of the table. These test items were correctly responded to as follows: 26 participants responded correctly to test items 1 and 3; 25 participants responded correctly to test items 2 and 6; 24 participants responded correctly to test items 8 and 12; 23 participants responded correctly to test items 7 and 11; and 22 participants responded correctly to test item number 14. The column labeled "stimulus" lists information that, as per test administration guidelines, each participant was given to assist in answering the test item.

Table 4-3:Least challenging test items, arranged in order of difficulty

Number correct (n=28)	*Test Item*	*Item Name*	*Stimulus*	*Correct Response*
26	1	Perception of Small Numbers	(Shown a picture) How many cats do you see?	2, 1, 3 or more
26	3	Verbal Counting by Ones: 1 to 5	(Shown a hand) Count the fingers for me	1 to 5 in correct order
25	2	Produce Finger Displays: 1,2, Many	Show me __ fingers. (i.e., 2, 1, 5)	2, 1, 3 or more
25	6	Enumeration: 1 to 5 items	(Shown a picture) You count the stars.	4, 5
24	12	Verbal Counting by Ones: 1 to 10	(Given 10 tokens) 1,2,3, now count by yourself.	Count 4 to 10
24	8	Nonverbal (Concrete) + & -	(Using tokens and a blank card to hide the total after the addition or subtraction of the second token) Make yours like mine. (2+1; 2-1; 1+3; 4-3; 2+2)	3 or 4; 1; 4 or 5; 1 or 2; 3,4 or 5
23	7	Cardinality Rule	(Using the same picture as in 6) How many stars did you count?	4, 5
23	11	Produce Finger Displays to 5	Hold up __ fingers (3,5,4)	3 , 5, 4
22	14	Reading Numerals: Single-Digit Numbers	(Shown numerals) What number is this?	2 , 5, 6

(Ginsburg & Baroody, 2003)

These 9 test items have two characteristics in common. First, all 9 items involve the use of some form of concrete manipulative (i.e., pictures, fingers, tokens, etc.). Second, all 9 test items involve quantities/numbers of 10 or less. Seven of the nine test items involve quantities less than 5. An analysis of the incorrect responses given for the least challenging test items indicates an underdeveloped number sense as demonstrated below.

Test item number 1 was answered incorrectly by only 2 participants. In this test item the child was shown three pictures of cats (i.e., 2 cats, 1 cat, and 3 cats) and asked "how many" were there. The two incorrect responses were as follows: the first child responded, “3” to each picture, meaning that he scored 1/3 correct; the other child responded, “2”, “3”, and “6”. This child answered 2/3 correctly (in the case of the last picture, the correct answer is “3” or anything greater than “2”). Scoring criteria however, required all three to be answered correctly to get credit for this item.

Test item number 3 was also answered incorrectly by only 2 participants. In this test item the child was shown the tester’s hand and asked to count the fingers. One child skipped the number 3 while counting. The other child appeared not to understand the question. Since it was believed that this test item may have been confusing when asked through sign (i.e., using hands to talk about counting part of the hand), the child was asked to count a manipulative other than fingers; 5 tokens. S/he then appeared to understand the question, however was unable to count accurately past “3” (i.e., 1, 2, 3, 1, 4, 6).

Test item number 2 was answered incorrectly by 3 participants. In this test item children were asked to hold up 2, 1, and 5 fingers. One child responded, “5” when asked to show “2” fingers; a second child responded, “2”, “3”, and “6”; and the third child counted 5 fingers for each question.

Test item number 6 was also answered incorrectly by 3 participants. In this test item, children were asked to count stars in two separate pictures (i.e., a picture of 3 stars and a picture of 5 stars). Children who answered this test item incorrectly indicated that they had not yet achieved mastery of the counting system. One child answered, “3” and “4” respectively; a second child answered, “3” and “3”; and a third child answered, “5” and “4.”

Test item number 12 was answered incorrectly by 4 participants. In this test item, ten tokens were laid out on a table. The researcher counted the first 3 tokens; the child was then asked to count the remaining tokens. Similar to test item number 6, children who answered this test item incorrectly indicated an incomplete mastery of the counting system. For one child, the question was beyond his/her ceiling score; one child counted 11 tokens (twice); another child counted successfully up to 6, then counted, “4,5,8,9”; and a third child counted successfully up to 8 then counted, “11,13.”

Test item number 8 was also answered incorrectly by 4 participants. In this test item the child was asked to demonstrate concrete awareness of nonverbal addition and subtraction using a display of tokens set up by the researcher. In view of the child, the researcher set up the quantity of tokens representing the first number. Still in view of the child, the researcher then hid the first group of tokens and added or took tokens away. The child was then asked to demonstrate the total number of tokens that should be present at the end of the problem. The three problems acted out were, “2+1”, “2-1”, “1+3”, “4-3”, and “2+2”. Two of the four children scoring incorrectly on this test item did not answer the question at all; of the other two, one answered the first two problems incorrectly (i.e., “2+1” and “2-1”), the other answered the third and fourth problems incorrectly (i.e., “1+3” and “4-3”).

Test item number 7 was answered incorrectly by 5 participants. In this test item the picture of stars from test item number 6 was used to test the child’s understanding of cardinality. After the child counted the stars, the researcher hid them under an index card. The child was then asked to tell how many stars were “hiding.” Three children were unable to answer the question without counting. One child signed “missed” repeatedly when the stars were hidden, and one responded, “6” and “4” when the stars were hidden.

Test item number 11 was answered incorrectly by 5 participants. This test item required children to hold up 3, 5, or 4 fingers when asked by the tester. Two of the participants who scored incorrectly on this test item did not answer the question; two counted to 5 for each part of the question; and one responded, “6”, “4”, and “5” respectively.

Test item number 14 was answered incorrectly by 6 participants. This test item required children to identify the number when shown a numeral in print (i.e., 2, 5, 6). Two of the children that scored incorrectly on this test item did not answer the question; one got only the first part wrong by answering, “1”, “5”, and “6” respectively; one child responded, “2”, “3” , and “4”; one child responded, “2,” “5”, and “9”; and one responded, “2”, “6”, and “3”.

As the description above indicates, incorrect responses on the least challenging test items were due either to counting errors, or difficulty with labeling numerals in print. Children answering these items incorrectly appear to have an incomplete understanding of the number/counting system for numbers less than 10. However, the majority of the children in this study had little difficulty answering these test items correctly.

4.1.1.2 Most Challenging Test Items

The 17 test items presented in Table 4-4 were answered incorrectly by 75% or more of participants (n ≥ 21) and are, therefore, considered the most challenging test items. However, 9 participants answered at least one of these 17 test items correctly. These 9 participants varied in age as follows: 8 participants were 5 years old, and 1 participant was 6 years old. Five of these 9 participants received TEMA-3 scores that ranked in the “more successful” range, and 4 received scores that ranked in the “average” range. Five of these participants had at least one deaf parent; the remaining 4 participants had hearing parents.

In Table 4-4 the most challenging test items are ranked in order of difficulty with the most challenging test items appearing at the bottom of the table. These test items were correctly responded to as follows: 6 participants responded correctly to test items number 28, 33, and 38;

5 participants responded correctly to test items number 16, 35, and 27; 4 participants responded correctly to test item number 40; 3 participants responded correctly to test item number 31; 2 participants responded correctly to test item number 22; 1 participant responded correctly to test items 30, 32, 36, and 39; and no participants responded correctly to test items 17, 25, 34, and 37.

Table 4-4: Most challenging test items, arranged in order of difficulty

Number correct (n=28)	*Test Item*	*Item Name*	*Stimulus*	*Correct Response*
6	28	Produce Sets: Up to 19 items	(Given 25 tokens) Give me exactly 19	19
6	33	Verbal Counting by 10s: Up to 90	Count by 10s like this: 10, 20, 30	40, 50, 60, 70, 80, 90
6	38	Enumeration: 11 to 20 items	(Shown dots on a page) Count these dots with your finger. (14, 16)	14; 16
5	16	Concretely Modeling + Word Problems: Sums up to 9	(Given 10 tokens and told 3 story problems about Joey and his tokens) How many does he have altogether? (1+2; 4+3; 3+2)	3, 7, 5
5	35	Reading Numerals: 2-Digit Numbers	(Shown numbers) What number is this? (28, 47, 90)	28; 47; 90
4	27	Mental Addition: Sums 5 to 9	(Shown a display of numbers) Which is closer to __; __ or __? (7, 1 or 9; 6; 4 or 10; 3, 5 or 9; 5, 1 or 7; 8, 1 or 6; 3, 1 or 6)	9; 4; 5; 7; 6; 1
4	40	Verbally Count Back from 20	Count backwards starting from 20	20 to 1 in correct order
3	31	Verbal Counting by Ones: Up to 42	Count up as high as you can.	At least 42
2	22	Number After: 2 Digit Numbers to 40	What number comes next; __ then comes …? (24, 33)	25, 34
1	30	Writing Numerals: 2-Digit Numbers	Write the number (23, 97)	23; 97
1	32	Counting On from the Larger Addend	How much is __ and __ more altogether? (2&7; 4&8; 3&9)	(must count up from first addend) 9; 12; 12
1	36	Number After: Decades	What number comes next: __, and then comes …? (29, 49)	30; 50

Table 4-4 (continued)

1	39	Number After: 2 Digit Numbers to 90	What number comes next; __, and then comes…? (69, 89)	70; 90
0	17	Part-Whole Concept	(Given 10 tokens and told 4 story problems) How many? (__ +3=5; __-2=7; __+4=7; __-3 = 4)	1 to 4; >7; <7; >4
0	25	Equal-Partitioning: Fair Sharing of Discrete Quantities	(Given 12 tokens and told 2 story problems) Share 12 between 2; Share 12 among 3.	6,6; 4,4,4
0	34	Symbolic Additive Commutativity	(Shown number sentences) Which number sentences here are correct for this word problem?	9+7, 7+9; 8-5; 7+6, 6+7
0	37	Mental Number Line: 2-Digit Numbers	(Shown number display) Which is closer to __; __ or __? (32, 24 or 61; 84, 51 or 96; 48, 24 or 53; 65; 49 or 99; 71, 49 or 84; 53, 22 or 67)	24; 96; 53; 49; 84; 67

(Ginsburg & Baroody, 2003)

The majority of these test items share 2 characteristics that may have caused difficulty for the children in this study. First, 14 of the test items involve quantities/numbers greater than 10; second, 11 of the 17 items compel the use of abstract thinking as they do not incorporate the use of manipulatives (e.g., tokens). In addition, of the 40 test items answered by the children in this study, 4 were story problems. Three of these test items were answered incorrectly by all participants, and one story problem was answered correctly by 5 participants. An analysis of the incorrect responses given for the most challenging test items is provided below.

Test item number 28 was answered incorrectly by 22 participants. In this test item, 25 tokens were laid out on the table. Children were asked to give 19 tokens to the researcher. For 17 children, this item was beyond their ceiling score. The remaining children gave the researcher varying amounts of tokens; 2 children counted tokens accurately up to a quantity smaller than 19 (i.e., 10, and 12), then gave the researcher all the tokens; 1 child gave the researcher 9 tokens; one child used a correct number string up to 19, but did not track while counting and gave the researcher all the tokens; and one child just gave the researcher 20 tokens without counting.

Test item number 33 was also answered incorrectly by 22 participants. In this test item, children were asked to count by 10s up to 90. The question was beyond the ceiling score for 20 children. The remaining 2 children gave the answer of “21.”

Test item number 38 was also answered incorrectly by 22 participants. In this test item, children were asked to count two pictures of dots scattered on a page. One page had 14 dots, the other had 16 dots. For 20 children, this question was beyond the ceiling score. For the remaining 2 children: 1 child guessed and responded without counting; the other had difficulty tracking causing him/her to count only one of the two pictures correctly.

Test item number 16 was answered incorrectly by 23 participants. This test item asked children to model and solve 3 story problems with sums up to 7 (1+2; 4+3; 3+2). This test item was beyond the ceiling score for 6 children. Of the remaining 17 children: 4 children did not give an answer; 4 children counted all of the tokens present; 5 children answered with a number from the problem; 2 children set up groups for each, but did not put them together to solve the problem; one child gave the answers of, “5”, “2” and “30”; and one child solved the first of the three problems correctly and then used the group of tokens set up from the first problem, adding a new group to it for each new problem solved.

Test item number 35 was also answered incorrectly by 23 participants. This test item asked children to read “aloud” 2-digit numbers presented in print (i.e., 28, 47, and 90). This test item was beyond the ceiling score for 20 children. Of the three remaining children: two signed each digit in the number separately (e.g., 2-8, rather than 28); one child read the first two numbers correctly, however s/he responded "19" for 90.

Test item number 27 was answered incorrectly by 24 participants. This test item required children to use mental addition with sums from 5 to 9. Children were shown a display of 3 numbers, one placed above and in between the other 2. Children were asked which of the two numbers was closest to the one in the middle. (i.e., Is "7" closer to 1 or closer to 9?). For 17 children, this question was beyond their ceiling score. One child did not answer; 3 children always chose the greater number; 3 children answered the question out of camera range therefore, beyond being scored as "incorrect" during testing, the exact answer they gave could not be retrieved from the videotape.

Test item number 40 was also answered incorrectly by 24 participants. This test item required children to count backwards starting at 20. This test item was beyond the ceiling score for 23 children. The one remaining child responded "I forget."

Test item number 31 was answered incorrectly by 25 participants. This test item required children to count by ones up to 42. This question was beyond the ceiling score for 18 children. Of the remaining children, 6 successfully counted up to a number smaller than 42 (i.e., 12, 20, 21, 22, 25, 32). Due to interviewer error, this question was skipped for 1 child.

Test item number 22 was scored incorrectly by 26 participants. This test item required children to say what number comes after 24 and after 33. This test item was beyond the ceiling score for 13 children. Two children did not answer; one child guessed, "8"; and one child counted up to 12. The remaining nine children gave a variety of numeric answers (i.e., 21 and 22; 35 and 34; 25 and 25; 5 and 55; 25 and 44; 25 and 24; 25 and 26; 50 and 165; 25 and 55).

Test item number 30 was scored incorrectly by 27 participants. This test item required children to write the numerals for two, 2-digit numbers (i.e., 23 and 97). This test item was beyond the ceiling score for 19 children. The 8 remaining children wrote various numerals, 3 of which approximated the correct response (i.e., 79 for 97; 32 for 23 – responses from two different children).

Test item number 32 was scored incorrectly by 27 participants. This test item required children to solve three story problems telling how many cookies Cookie Monster would have when two quantities were added together (i.e., 2 & 7; 4 & 8; 3 & 9). As per test administration guidelines, children had to count up from the larger addend to score correctly on this item. This test item was beyond the ceiling score for 20 participants. Of the 7 remaining children: 1 child did not answer; 4 children responded with numbers from the problem; the remaining 2 children used the shape of the sign on their hands to solve the problem. These two children put the signs for numbers from the problems on their hands and counted their fingers as manipulatives (i.e., when the sign for "8" is on one hand, and the sign for "4" is on the other hand, 7 fingers will be "standing". These two children counted these fingers and gave "7" as an answer to the problem).

Test item number 36 was also scored incorrectly by 27 participants. This test item required children to demonstrate their knowledge of decades by saying what number came next (i.e., after "29" and after "49"). This test item was beyond the ceiling score for 20 children. The remaining 7 children gave various numeric responses (i.e., '3 ten' and 95; 30 and 95, from two children; 20 and 50; '20 ten' and (out of camera range); 30 and 43; 30 and 95).

Test item number 39 was also scored incorrectly by 27 participants. This test item also required children to say what number comes next using numbers up to 90 (i.e., after "69" and after "89"). This test item was beyond the ceiling score for 23 children. Of the remaining 4 children: 1 child was out of camera range, the remaining 3 gave various numeric answers (i.e., 91 and 90; 10 and 90; 80 and 90).

Test item number 17 was scored incorrectly by all participants. This test item required children to solve 4 story problems involving part-whole concepts (__ + 3 = 5; _. – 2 = 7; _ + 4 = 7; _ -3 = 4). This test item was beyond the ceiling score for 10 children. Of the remaining 17 children: 5 children did not solve any of the problems; 3 children counted all the tokens available; 2 children answered with numbers from the problem; 1 child answered with a number that was 1 bigger than the last number said (i.e., 6, 8,8,7); 5 children appeared to guess; and for 1 child this question was skipped due to interviewer error.

Test item number 25 was scored incorrectly by all participants. This test item required children to solve 2 story problems involving equal-partitioning or fair sharing (i.e., sharing 12 between 2; sharing 12 among 3). This test item was beyond the ceiling score for 16 children. Of the remaining 12 children: 3 children did not solve any of the problems; 2 children solved the first part correctly (dividing among 2 people), but answered the second part with a number from the problem, "3"; 4 children responded with numbers from the problem; 2 children guessed; and 1 child responded to both problems by distributing both groups unevenly including an explanation for the first grouping (only five "cookies" were distributed to each sibling in the first problem, so that two could be "saved for Mom and Dad"). Although this child appeared to understand the problem situation and the concept of fair-sharing, following test guidelines, his response was scored as incorrect.

Test item number 34 was scored incorrectly by all participants. This test item required children to demonstrate their understanding of symbolic additive commutativity by circling number sentences on a page to match a story problem told to them. This test item was beyond the ceiling score for 10 children. The remaining 18 children circled random numbers on the page.

Test item number 37 was scored incorrectly by all participants. This test item required children to use a mental number line for 2-digit numbers. Children were shown a display of 3 numbers, one placed above and in between the other 2. Children were asked which of the two numbers was closest to the number in the middle (i.e., is 32 closer to 24 or 61?). This test item was beyond the ceiling score for 20 children. Five of the remaining children were out of camera range so the pattern of their responses is unknown; two children answered two of the problems correct, possibly by guessing; and the one remaining child always chose the greater number.

As the above description indicates, the most frequent reason for why a child scored incorrectly on a test item was that it was beyond his or her ceiling score. Of children that did answer the most challenging test items, the majority of incorrect responses appeared to fall into three categories: an inability to accurately count to large numbers (e.g., when asked to give the researcher 19 tokens, children accurately counted up to a smaller number (e.g., 12) then gave the researcher all available tokens); difficulty with labeling large numbers in print (e.g., child reads "2-8" rather than "28"), and difficulty with the abstract thinking required to successfully solve story problems. Children's error types when answering test items including story problems largely fell into 3 categories: answering with a number from the problem; counting all available manipulatives; and/or not solving the problem at all.

4.1.2 Characteristics Related to Child

Participants' mathematics ability, as measured by scores on the TEMA-3, was analyzed for its relationship to various characteristics related to hearing loss. Data regarding characteristics related to hearing loss (i.e., etiology of hearing loss, age of onset, degree of hearing loss, use of assistive listening device) were reported by parents on a background questionnaire (Appendix A). Completed background questionnaires were received from families of 24 participants. For questionnaires that were not returned, as much information as possible was provided by the school. Data were entered into an SPSS database. Due to small sample size, nonparametric statistics were initially performed using the Mann-Whitney Test to test for differences between two independent categorical variables on a continuous independent variable (test score) and the Kruskal-Wallis Test to test for differences among three or more independent categorical variables on a continuous independent variable (test score). The more powerful parametric alternatives of these statistical techniques however, an independent-samples t-test and one-way between groups analysis of variance (ANOVA) respectively, were found to yield the same results and are, therefore, the statistics reported in the sections that follow. Given the small sample size for this study (n=28), a large contrast between groups was required for the difference to be significant. For this reason, statistical findings must be accepted with caution.

4.1.2.1 Age

Participants' ages were distributed by rank as indicated in Table 4-5. In terms of age, participants' scores on the TEMA-3 can be described as follows: of the 7 participants who were 4 years old, 5 achieved scores in the "average" range, 1 achieved a score in the "more successful" range, and 1 achieved a score in the "less successful" range. Of the 19 participants who were 5 years old, 8 achieved scores in the "average" range, 5 achieved scores in the "more successful" range, and 6 received scores in the "less successful" range. Both participants who were 6 years old achieved scores in the "average" range.

Table 4-5: Age by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Age 4 years	1	5	1	7
Age 5 years	5	8	6	19
Age 6 years	0	2	0	2
Total	6	15	7	28

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of age on mathematics achievement, as measured by mathematics ability scores on the TEMA-3. Participants were divided into three groups according to age (age 4; age 5; age 6). The difference between the three groups was not significant at the .05 alpha level (p=.923). The mean score on the TEMA-3 achieved by children in each of the three age groups (age 4: M = 89.71; age 5: M = 87.95; age 6: M = 86.00) did not differ significantly from the mean score achieved by children in any other age group.

4.1.2.2 Etiology of Hearing Loss

In terms of etiology of hearing loss, participants in this study (n = 28) can be described as follows: heredity/genetics was the cause of hearing loss reported for 14 participants; illness was the cause for 1 participant; a physical malformation of the auditory anatomy was the cause for 2 participants. The cause of hearing loss was unknown for 11 participants (6 participants reported the cause of their child’s hearing loss as unknown; the remaining 5 “unknowns” are due to missing data). Participants’ etiology of hearing loss was distributed by rank as indicated in Table 4-6.

Table 4-6: Etiology of hearing loss by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Genetic	3	8	3	14
Illness	0	0	1	1
Physical Malformation of auditory anatomy	0	1	1	2
Unknown	3	6	2	11
Total	6	15	7	28

A one-way between-groups analysis of variance (ANOVA) was conducted to explore the impact of etiology of hearing loss on mathematics achievement, as measured by mathematics ability score on the TEMA-3. Participants were divided into three groups according to the etiology of their hearing loss (genetic; illness; physical malformation of the auditory anatomy). The difference between the groups was not significant at the .05 alpha level (p=.072). The mean score on the TEMA-3 achieved by children in each group (genetic: M = 88.71; illness: M = 68.00; physical malformation of the auditory anatomy: M = 73.5) did not differ significantly from children in any other group, although there was a trend for children with genetic etiology to score higher. This trend was further explored using an independent-samples t-test to compare the mathematics ability scores of children who had a hearing loss with a genetic etiology to children for whom the etiology was not genetic. The difference between the scores of children with a genetic etiology was significantly different from the scores of children who did not have a genetic etiology at the .05 alpha level (p=.022). The mean score of children with a genetic etiology (M = 88.71, SD = 10.96) was higher than the mean score for children who did not have a genetic etiology (M = 71.67, SD = 6.35).

4.1.2.3 Age of Identification

In terms of age of identification, participants in this study (n = 28) can be described as follows: hearing loss was discovered at the time of birth for 11 participants; identification occurred after birth yet younger than 1 year (< 12 months) for 4 participants; identification occurred when the child was older than one year yet below 2 years (12 months – 23 months) for 5 participants; identification occurred after the age of 2 years yet below 3 years (24 months – 36 months) for 2 participants; and the time of discovery of hearing loss was unknown for 6 participants. Age of identification was unknown for one participant as s/he was adopted at the age of 4 years; the remaining 5 "unknowns" are due to missing data (i.e., background questionnaires that were not returned). Participants' age of identification, as distributed by rank, is indicated in Table 4-7.

Table 4-7: Age of identification by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Birth	4	6	1	11
<12 months	2	2	0	4
12 months – 23 months	0	2	3	5
24 months -36 months	0	1	1	2
Unknown	0	4	2	6
Total	6	15	7	28

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of age of identification on mathematics achievement, as measured by mathematics ability score on the TEMA-3. Participants were divided into 4 groups according to the age when their hearing loss was identified (birth; 1 month to 11 months; 12 months to 23 months; 24 months to

36 months). There was a statistically significant difference at the .05 alpha level in mathematics ability for the four groups [F=4.432, p=.017]. Although the actual difference in mean scores between children for whom hearing loss was discovered at younger than one year of age (birth: M = 94.55 and < 12 months: M = 95.00) and children for whom hearing loss was discovered later (12 months to 23 months: M = 77.40 and 24 months to 36 months: M = 76.50) was quite large, post-hoc comparisons using the Tukey HSD test, indicated only that the mean score for children for whom hearing loss was discovered at birth (M = 94.55, SD = 10.034) was significantly different than for children for whom hearing loss was discovered between the ages of 12 months to 23 months (M = 77.40, SD = 10.74).

4.1.2.4 Degree of Hearing Loss

Information regarding degree of hearing loss was obtained through use of an open-ended item on the background questionnaire. Parents filled in their child's hearing loss using the terms "moderate," "severe", and "profound." These terms are typically used to label levels of hearing loss as follows: a moderate loss is equivalent to 56-70 decibels; a severe loss is 71-90 decibels; and a profound loss is 91 decibels or greater (Schow & Nerbonne, 1989). In terms of degree of hearing loss, participants in this study (n=28) can be described as follows: 1 participant had a moderate hearing loss; 4 participants had a severe loss; 12 participants had a profound loss; and for 11 participants the degree of hearing loss was not reported. The degree of hearing loss was unknown for 11 participants (6 participants reported that the degree of their child's hearing loss was unknown; the remaining 5 "unknowns" are due to missing data). Participants' degree of hearing loss was distributed across rank as indicated in Table 4-8.

Table 4-8: Level of hearing loss by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Moderate	1	0	0	1
Severe	2	1	1	4
Profound	1	8	3	12
Unknown	2	6	3	11
Total	6	15	7	28

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of degree of hearing loss on mathematics ability, as measured by mathematics achievement score on the TEMA-3. Participants were divided into 3 groups according to the level of their hearing loss (moderate; severe; profound). The difference between the groups was not significant at the .05 alpha level ($\underline{p}$=.228). The mean score on the TEMA-3 achieved by children in each group (moderate: M = 104.00; severe: M = 94.25; profound: M = 84.83) did not differ significantly from children in any other group.

Since the quantity of children with a profound hearing loss ($\underline{n}$=12), was greater than that of children with any other degree of loss (moderate: $\underline{n}$=1; severe: $\underline{n}$=4), an independent-samples t-test was conducted to compare the mathematics ability scores of children with a profound hearing loss ($\underline{n}$=12) to children with less than a profound hearing loss ($\underline{n}$=5). At the .05 alpha level, the scores of children with a profound hearing loss were not significantly different from the scores of children with less than a profound hearing loss ($\underline{p}$=.108). The mean score of children with a profound hearing loss (M = 84.83, SD = 11.75) was not significantly different from the mean score of children with less than a profound hearing loss (M = 96.20; SD = 14.30).

4.1.2.5 Use of Assistive Listening Devices

With regard to the use of assistive listening devices, participants in this study (n = 28) can be described as follows: 20 participants reported using an assistive listening device (5 participants reported having a cochlear implant; 15 participants reported use of hearing aids at least some of the time); 5 participants reported using no assistive listening device; and for 3 participants (due to missing data) it is unknown whether any assistive listening device was used. Participants' use of assistive listening device, as distributed by rank, is indicated in Table 4-9.

Table 4-9: Use of assistive listening device by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Uses device	5	11	4	20
Does not use device	1	1	3	5
Unknown	0	3	0	3
Total	6	15	7	28

An independent-samples t-test was conducted to compare the mathematics ability scores of children who did and did not use an assistive listening device. The difference between the scores of children who did (*M* = 88.5, *SD* = 12.48) and did not (*M* = 101.00, *SD* = 2.83) use an assistive listening device was not significant at the .05 alpha level. Although there was a trend for children who did not use an assistive listening device to score higher, only a small number of children fell into this category (n=5).

4.1.3 Characteristics Related to Parents

Participants' mathematics ability, as measured by scores on the TEMA-3, was analyzed for its relationship to various characteristics related to parents. Data regarding characteristics related to parents (i.e., parental hearing status, level of education, participation in an early-intervention program, signing skills) were reported by parents on a background questionnaire (Appendix A). Completed background questionnaires were received from families of 24 participants. For questionnaires that were not returned, as much information as possible was provided by the school. Data were entered into an SPSS database. Due to small sample size, nonparametric statistics were initially performed using the Mann-Whitney Test to test for differences between two independent categorical variables on a continuous variable (test score), and the Kruskal-Wallis Test to test for differences among three or more independent categorical variables on a continuous independent variable (test score). The more powerful parametric alternatives of these statistical techniques however, an independent-samples t-test and one-way between groups analysis of variance (ANOVA) respectively, were found to yield the same results and are therefore the statistics reported in the sections that follow. Given the small sample size for this study (n=28), a large contrast between groups was required for the difference to be significant. For this reason, statistical findings must be accepted with caution.

4.1.3.1 Parents' Hearing Status

The hearing status of parents of participants was distributed by rank as indicated in Table 4-10. In terms of parents' hearing status, participants' scores on the TEMA-3 can be described as follows: of the 12 participants who had hearing parents, 1 achieved a score in the "more successful" range, 6 achieved scores in the "average" range, and 5 achieved scores in the "less successful" range. Of the 16 participants who had deaf parents, 5 achieved scores in the "more successful" range, 9 achieved scores in the "average" range, and 2 achieved scores in the "less successful" range.

Table 4-10: Parents' hearing status by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Hearing parents	1	6	5	12
At least one deaf parent	5	9	2	16
Total	6	15	7	28

An independent-samples t-test was conducted to compare the mathematics ability scores of children with hearing parents to the scores of children with at least one deaf parent. At the .01 alpha level, the difference between the scores of children with hearing parents was significantly different from the scores of children with at least one deaf parent (p=.008). The mean score of deaf children with at least one deaf parent (M = 93.44, SD = 10.95) was significantly different from the mean score of deaf children with hearing parents (M = 81.33, SD = 11.19).

4.1.3.2 Parents' Level of Education

In terms of parents' level of education, mothers of participants (n = 28) in this study can be described as follows: 5 mothers had a high school diploma or less; 7 mothers had a degree other than a bachelors' or masters' degree (e.g., associates'); 10 mothers had a college or graduate degree; and for 6 mothers the education level was unknown. Mothers' education level was distributed by rank as indicated in Table 4-11.

Table 4-11: Mothers' education level by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
High School diploma or less	1	4	0	5
Other degree (e.g., associates)	2	3	2	7
College or graduate degree	3	5	2	10
Unknown	0	3	3	6
Total	6	15	7	28

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of mothers' education level on mathematics achievement, as measured by mathematics ability scores on the TEMA-3. Participants were divided into three groups according to their mothers' education level (high school diploma or less; other degree; college or graduate degree). The difference between the three groups was not significant at the .05 alpha level (p=.984). The mean score on the TEMA-3 achieved by children in each of the three groups (high school diploma or less: M = 90.20; other degree: M = 90.00; college or graduate degree: M = 89.10) did not differ significantly from the mean score achieved by children in any other group.

In terms of parents' education level, fathers of participants in this study can be described as follows (n = 28): 13 fathers had a high school diploma or less; 4 fathers had some other form of degree (e.g., associates'); 4 fathers had a college or graduate degree; and for 7 participants the father's education level was unknown. Fathers' education level was distributed by rank as indicated in Table 4-12.

Table 4-12: Fathers' education level by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
High School diploma or less	5	6	2	13
Other degree (e.g., associates)	0	4	0	4
College or graduate degree	1	1	2	4
Unknown	0	4	3	7
Total	6	15	7	28

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of fathers' education level on mathematics achievement, as measured by mathematics ability scores on the TEMA-3. Participants were divided into three groups according to their fathers' education level (high school diploma or less; other degree; college or graduate degree). The difference between the three groups was not significant at the .05 alpha level (p=.329). The mean score on the TEMA-3 achieved by children in each of the three groups (high school diploma or less: M = 92.54; other degree: M = 90.00; college or graduate degree: M = 81.50) did not differ significantly from the mean score achieved by children in any other group.

4.1.3.3 Participation in an Early Intervention Program

In terms of participation in an early intervention (EI) program, families of participants can be described as follows: 18 families participated in early-intervention programs and 4 families did not. For 6 families it is unknown if there was participation in an early intervention program (due to missing data). Participation in an early intervention program was distributed across rank as indicated in Table 4-13.

Table 4-13: Participation in an EI program by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
EI services received	4	9	5	18
EI services not received	1	3	0	4
Unknown	1	3	2	6
Total	6	15	7	28

An independent-samples t-test was conducted to compare the mathematics ability scores for children who did and did not receive early intervention services. There was no significant difference in scores for children who did (M = 86.83, SD = 12.94) and did not (M = 95.00, SD=7.30) receive early intervention services.

4.1.3.4 Signing Skills/Exposure to Sign Language in the Home

Children's exposure to sign language in the home was examined using a self-reported categorical rating scale (see background questionnaire, Appendix A). Mothers of participants (n = 28) rated themselves as follows: 1 had no signing skills; 4 were "beginners"; 3 were "pretty good"; 3 were "good"; 12 were "fluent"; and the signing skills of 5 mothers are unknown. Fathers of participants (n = 28) rated themselves as follows: 5 were "beginners"; 1 was "pretty good"; 2 were "good"; 11 were "fluent"; and the signing skills of 9 fathers are unknown.

To examine the relationship between participants' exposure to sign language in the home and mathematical ability, the self-reported rating scale was re-interpreted. Participants' exposure to sign language was coded according to the parent with the highest reported skill level. Participants were coded as having: "fluent" exposure to sign language in the home if at least one parent had "fluent" signing skills; "good" exposure to sign language in the home if at least one parent had "good" signing skills; and "limited to no" exposure to sign language in the home if both parents had "pretty good" signing skills or less. As reported in Table 4-14, overall, participants came from homes that can be described as follows: 12 had "fluent" exposure to sign language; 6 had "good" exposure to sign language; 5 had "limited to no" exposure to sign language; and 5 had an unknown level of exposure to sign language.

Table 4-14: Exposure to sign in the home by mathematics achievement score grouping

	More successful	*Average*	*Less successful*	*Total*
Fluent	5	6	1	12
Good	1	3	1	5
None/limited	0	3	3	6
Unknown	0	3	2	5
Total	6	15	7	28

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of exposure to sign language in the home on mathematics achievement, as measured by mathematics ability score on the TEMA-3. Subjects were divided into three groups according to their parents' signing skills (none/limited; good; fluent). There was a statistically significant difference at the .05 alpha level in mathematics ability scores for the three groups (F=5.213; p=.015). Post-hoc comparison using the Tukey HSD test indicated that the mean score for children with "none/limited" exposure to sign language in the home (M = 78.83, SD = 10.068) was significantly different from children with "fluent" exposure to sign language in the home (M = 95.50, SD = 9.840). Children with "good" exposure to sign language in the home (M = 85.60, SD = 13.240) did not differ significantly from children in either of the other two groups.

4.1.4 Section Summary

As discussed in this section, characteristics that appear to contribute to mathematical achievement in young deaf children include: age of identification (i.e., participants for whom hearing loss was identified at a younger age scored higher on the TEMA-3 than did participants for whom hearing loss was discovered later); parents' hearing status (i.e., participants from homes with at least one deaf parent scored higher on the TEMA-3 than did participants with hearing parents); and exposure to sign language in the home (i.e., participants with "fluent" exposure to sign language in the home scored higher on the TEMA-3 than did participants with "limited to no" exposure to sign language).

To further examine the knowledge held by young deaf children in contexts broader than mathematics, and the possibility that the additional knowledge that children bring to tasks also contributes to their mathematical achievement, three children were randomly selected from the "more successful" and "less successful" groups to participate in the second level of this study. In the next section, young deaf children's knowledge in the area of basic concepts will be discussed.

4.2 UNDERSTANDING OF BASIC CONCEPTS

To further examine characteristics that might be associated with mathematics achievement, as demonstrated by mathematics ability score on the TEMA-3, three children were selected from the "more successful" and "less successful" groups to participate in Level 2 of this study. In this section, the understanding of basic concepts demonstrated by these 6 participants will be described in terms of scores on the Bracken Basic Concept Scale-Revised (BBCS-R), and observed performance during the Parent-Child Activity (PCA), Researcher-Child Activity (RCA), and Full-Day Observation (FDO). First, scores from the BBCS-R will be discussed, then the performance of each group (i.e., “more successful” and “less successful”) will be discussed in terms of each of the following eight basic concepts: Number and Operations; Geometry and Spatial Sense; Measurement; Algebraic Thinking; Problem Solving; Personal Awareness; Social Awareness; and Early Literacy).

4.2.1 Bracken Basic Concept Scale-Revised Results

The BBCS-R was administered to the 6 children that participated in the second level of the study. Based on the numerical scores on the *school readiness composite* (SRC) and the remaining subtests, a normative conceptual classification, based on BBCS-R norms, was obtained. The BBCS-R normative conceptual classification for the test has established score ranges from “very delayed” to “very advanced”. “Average” refers to scores within one standard deviation of the normative mean score. Scores one and two standard deviations above the normative mean represent “advanced” and “very advanced” levels of understanding respectively; scores one and two standard deviations below the mean represent “delayed” and “very delayed” levels of understanding respectively.

As findings reported in Table 4-15 indicate, the scores of participants from the “more successful” group were higher than the scores of participants in the “less successful” group. On the SRC, which includes the concepts of color, letters, numbers/counting, sizes, comparisons, and shapes, participants’ scores were as follows: 2 participants in the “more successful” group scored in the “advanced” range and one scored in the “average/advanced” range; in the “less successful” group, two participants scored in the “average” range, while one scored in the “delayed” range. On the *direction/position* subcomponent, two participants in the “more successful” group scored in the “advanced” range and one scored in the “average” range; in the “less successful” group all three participants scored in the “very delayed” range. On the *self-social awareness* subcomponent, 1 participant in the “more successful” group scored in the “very advanced” range and 2 scored in the “advanced” range; in the “less successful” group, 2 participants scored in the “very delayed” range and 1 scored in the “delayed” range. On the *texture/material* subcomponent, 1 participant in the “more successful” group scored in the “advanced” range and two participants scored in the “average” range; in the “less successful” group, one participant scored in the “very delayed” range, one scored in the “delayed” range and, due to researcher error, a score is missing on the third participant. On the subcomponent of *quantity*, two participants in the “more successful” group scored in the “average” range and 1 scored in the “advanced” range; in the “less successful” group, two participants scored in the “very delayed” range and one scored in the “delayed” range. On the final subcomponent, *time/sequence*, all three participants in the “more successful” group scored in the “average” range; in the “less successful” group, two participants scored in the “very delayed” range and one scored in the “average” range.

Table 4-15: BBCS-R Results

	MS 1	*MS 2*	*MS 3*	*LS 1*	*LS 2*	*LS 3*
School Readiness Composite	Advanced	Average/ Advanced	Advanced	Average	Delayed	Average
Direction/ Position	Advanced	Average	Advanced	Very Delayed	Very Delayed	Very Delayed
Self-Social Awareness	Advanced	Very Advanced	Advanced	Very Delayed	Very Delayed	Delayed
Texture/ Material	Advanced	Average	Average	Very Delayed	(Missing)	Delayed
Quantity	Average	Average	Advanced	Very Delayed	Very Delayed	Delayed
Time/ Sequence	Average	Average	Average	Very Delayed	Very Delayed	Average

*Note: MS = Most Successful

As Table 4-16 indicates, mean scores on the SRC component of the BBCS-R were as follows: For colors, the highest score possible is 11 points, the mean score for the "more successful" group was 11, the mean score for the "less successful" group was 9.7; for letters, the highest score possible is 16, the mean score for the "more successful" group was 15.7, the mean score for the "less successful" group was 14.3; for numbers/counting, the highest score possible is 19, the mean score for the "more successful" group was 18.7, the mean score for the "less successful" group was 15.3; for sizes, the highest score possible is 12, the mean score for the "more successful" group was 8, the mean score for the "less successful" group was 5; for comparisons, the highest score possible is 10, the mean score for the "more successful" group was 8; the mean score for the "less successful" group was 3.3; for shapes, the highest score possible is 20, the mean score for the "more successful" group was 17.3, the mean score for the low group was 10.7.

Children in both groups received their lowest scores on the sub-sections of sizes, and comparisons. On the sizes subsection, children in the "more successful" group answered 67% of the questions correctly, children in the "less successful" group answered 42% of the questions correctly; on the comparisons subsection, children in the "more successful" group answered 80% of the questions correctly, children in the "less successful" group answered 33% of the questions correctly.

Table 4-16: Scores on the SRC by group

	Highest Score Possible	*"More successful" Group Mean Score*	*"Less successful" Group Mean Score*
Colors	11	11	9.7
Letters	16	15.7	14.3
Numbers/Counting	19	18.7	15.3
Sizes	12	8	5
Comparisons	10	8	3.3
Shapes	20	17.3	10.7

An independent-samples t-test was conducted to compare the performance of children in the "more successful" and "less successful" groups on the subcomponents of the *school readiness composite* of the BBCS-R. The difference between the two groups was not significant for five of the six subcomponents (color: p=.374; letters: p=.230; numbers: p=.292; sizes: p=.503; shapes: p=.179). At the .05 alpha level, the difference between the two groups was significant for the subcomponent of "comparisons" (p=.033). Children who were "more successful" (M = 8.0, SD = 2.00) scored higher on this subcomponent than did children who were "less successful" (M = 3.33, SD = 1.53).

4.2.2 Knowledge of Basic Concepts in a Non-Test Situation

In order to assess participants' knowledge of basic concepts in non-test situations, 3 additional instruments were used for data collection: a structured Parent-Child Activity (PCA); a structured Researcher-Child Activity (RCA); and a Full-Day Observation (FDO). The PCA and the RCA were designed specifically to access young children's knowledge of basic concepts through the use of classification activities. The FDO provided the researcher with the opportunity to observe the child's use of basic-concept information in a naturalistic environment.

Quantities for episodes of observed use of basic concepts by children in the "more successful" and "less successful" groups are reported by group in Table 4-17. The greatest differences between the two groups are within the strands of *Problem Solving* and *Social Awareness*.

Table 4-17: Basic Concepts, Episodes of use by group

Basic Concepts (PI, PCA, RCA, FDO)		*Episodes of Use*	
		More successful	*Less successful*
Mathematics Concepts	*Number & Operations*	38	36
	Geometry	18	30
	Measurement	33	17
	Algebraic Thinking	79	76
	Problem Solving	31	5
Personal/Social Awareness	*Personal Awareness*	83	104
	Social Awareness	112	48
Early Literacy	*Literacy*	29	18

The differences between children in the "more successful" (MS) and "less successful" (LS) groups were further broken down by child, as reported in Table 4-18.

Table 4-18: Basic concepts, Episodes of use by child

Basic Concepts (PI, PCA, RCA, FDO)		*Episodes of Use*							
		MS 1	*MS 2*	*MS 3*	*MS Total*	*LS 1*	*LS 2*	*LS 3*	*LS Total*
Mathematics Concepts	*Number & Operations*	11	14	13	**38**	19	7	10	**36**
	Geometry	7	6	5	**18**	11	5	14	**30**
	Measurement	8	13	12	**33**	3	5	9	**17**
	Algebraic Thinking	23	27	29	**79**	36	21	19	**76**
	Problem Solving	2	16	13	**31**	0	0	5	**5**
Personal/Social Awareness	*Personal Awareness*	38	24	21	**83**	36	31	37	**104**
	Social Awareness	43	38	31	**112**	31	7	10	**48**
Early Literacy	*Literacy*	14	7	8	**29**	12	5	1	**18**

An independent-samples t-test was conducted to compare totals on episodes of use for each concept for children in the "more successful" and "less successful" groups. At the .05 alpha level, there was no significant difference in the total number of episodes of use, for any basic concept (number and operations: p=.866; geometry: p=.214; measurement: p=.084; algebra: p=.868; problem solving: p=.131; personal awareness: p=.276; social awareness: p=.062; literacy: p=.399). Given the small sample size (n=6), a large contrast would have been required for the difference to be significant; therefore, these statistical findings must be accepted with caution.

4.2.2.1 Mathematics Concepts

The first five concept strands discussed below relate to children's understanding of mathematics concepts in the areas of: Number and Operations; Geometry and Spatial Sense; Measurement; Algebraic Thinking: and Problem Solving. The discussion of each concept begins with a table depicting the quantity of episodes of observed use for each concept strand. This is followed by an explanation of how children in each group (i.e., "more successful" and "less successful") demonstrated understanding of each concept strand under discussion.

Number and Operations

As demonstrated in Table 4-19, children in both the "more successful" and "less successful" groups used *number and operations* concepts with approximate equivalent frequency overall. Children in the "more successful" group however, used *number and operation* concepts twice as frequently as the "less successful" group during the PCA. Children in the "less successful" group used *number and operations* concepts twice as frequently during the RCA. As reported previously, at the .05 alpha level, the overall difference in quantity of use between the two groups was not significant (p=.866).

Table 4-19: Number and operations, Episodes of use by group

Instrument	*More successful*	*Less successful*	*Total*
PI	0	1	1
FDO	15	13	28
PCA	15	7	22
RCA	8	15	23
Total	38	36	74

When use of concepts in this area was analyzed qualitatively, children in both groups were observed to use *number and operation* concepts for the following purposes: to label numbers in the environment; to count/express quantities; and to use mathematical language to make comparisons. The number of times that each child in the “more successful” group and the “less successful” group was observed to use each of these themes is reported in Table 4-20. In terms of quantity, the greatest difference between the two groups was in the area of using mathematical language to make comparisons. Children in the “more successful” (MS) group used mathematical language more frequently than did children in the “less successful” (LS) group.

The numbers in the “total” rows of Table 4-19 (38, 36) and Table 4-20 (37, 34) do not match because although, using the Basic Concepts Coding Scheme, an episode may have been coded as demonstrating knowledge in the *number and operations* strand, the knowledge represented by specific episodes did not occur frequently enough to establish a theme.

Table 4-20: Number and operations <u>themes</u>, per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Use number labels	3	1	3	**7**	8	0	4	**12**
Count/express quantity	3	10	6	**19**	10	6	4	**20**
Use mathematical language to make comparisons	3	3	5	**11**	0	1	1	**2**
Total	9	14	14	**37**	18	7	9	**34**

An independent-samples t-test was conducted to compare totals on episodes of use for *number and operations* concepts for children in the "more successful" and "less successful" groups. At the .05 alpha level, the difference was not significant for two of the three themes (use number labels: p=.526; counts/expresses quantity: p=.907). The exception was "uses mathematical language to make comparisons." In this theme, children in the "more successful" group (*M* = 3.67, *SD* = 1.16) scored significantly higher than children in the "less successful" group (*M* = .67, *SD* = .577) (p=.016). This is consistent with findings from the BBCS-R in which children in the "more successful" group demonstrated an ability to make comparisons, as measured by test score on the "comparisons" subcomponent of the test, that was significantly higher (*M* = 8.0; *M* = 3.3; p=.033) than the score of children in the "less successful" group.

Given the small sample size (n=6), however, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively, as reported below. The performance of children in the "more successful" and "less successful" groups is reported in terms of how the use of the three themes related to *number and operations (*i.e., using number labels; counting/expressing quantity; and using mathematical language to make comparisons) differed between children in the "more successful" and "less successful" groups.

Uses number labels:

Children's ability to label numbers in the environment was observed with the most frequency during the FDO. While children in both groups were observed to label numbers in the environment, they used these labels differently. For children in the "less successful" group, the numbers expressed were simply labels. For example, when getting dressed, one child from the "less successful" group put on a shirt that had a "22" on it. She proudly announced "2-2!" as she pointed the number out to the researcher. Another example occurred as the same child played with a phone and labeled the numbers as she pressed them, then again later when she announced the television channel she wanted to watch, “3-3.” A different child from the “less successful” group labeled each number from 6-10 as he found them while playing a computer game.

When children in the “more successful” group used numbers as labels, these labels appeared to serve a more functional purpose. For example, when one child in the “more successful” group identified the number “20” when he saw it on a milk carton he asked his mother what it meant. Later in the day, the same child saw the number “42” on his father’s lawnmower. Although he labeled it as “24” he knew the number had a purpose. He said, “that means it goes really fast.” A different child in the “more successful” group showed the researcher the weather and temperature displayed on her mother’s pager. She read the number “68” and stated “its 68, it’s hot.”

Count/express quantity:

Children in both groups demonstrated an ability to count. Children in the “more successful” group however, were observed counting accurately to higher numbers (e.g., 21, 12; and 35) than children in the “less successful” group. No child in the “less successful” group was observed to accurately count to a number higher than 10. Children in both groups demonstrated their counting skills within a variety of contexts. A child in the “less successful” group accurately counted to ten as he played with an airplane during the RCA. He counted “1,2,3,4,5,6,7,8,9,10” before making the toy plane take off. Another child from the “less successful” group also demonstrated an ability to count accurately to 10 during the RCA. She counted a large group of buttons, but lost the counting string after 10 and counted the buttons as follows: “1,2,3,4,5,6,7,8,9,10, 16, 18, 19, 16, 1,2,3, 30,30, 16, 17, 18, 19, 16, 18, 30…” During the FDO, upon his mother's request, another child from the "less successful" group accurately counted 9 dogs on a border in the veterinarian's office.

Children in the "more successful" group demonstrated an ability to count to numbers greater than 10. During the PCA one child counted "12" items upon request, another counted "35". Children in this group also made use of large numbers to refer to numbers beyond what they were able to count to or conceptualize, for example, during the FDO a child used "100" to refer to his father's age.

Beyond counting, children in both groups also used numbers to express their knowledge of quantity. A child in the "less successful" group demonstrated her ability to determine quantity during the RCA when she announced that there were "Two pink!" buttons on the table. Another child in the "less successful" group demonstrated understanding of quantity during the PCA when he found "4 hard things" upon his mother's request. Children in the "more successful" group also demonstrated their understanding of quantity during the PCA. After sorting materials, children were frequently asked by a parent "how many" items were in the group they made. This question was usually answered correctly, however if the number counted was incorrect, children in the "more successful" group also demonstrated an ability to add items without recounting. This was demonstrated in the following exchange between one child in the "more successful" group and her father:

Child: (*counts items sorted)*, 11.

Father: You missed one.

Child: (*finds the missing item in the large pile and adds it to her group)*. Oh, 12.

Children in both groups demonstrated an ability to answer the question "how many?" A child in the "less successful" group expressed this understanding during the FDO. While in the veterinarian's office, the child's mother asked him how many dogs were on a border. The child counted and said, "9."

Additionally, a child in the "more successful" group demonstrated her ability to use a calendar as a tool to solve a problem involving quantity. While sitting in the kitchen the child was trying to remember how many times the researcher had visited her home. She looked at the calendar and said, "You're here today, 20 (May 20th), you were here 13 too (May 13th), and 17 (May 17th). Three times."

Uses of mathematical language to express quantitative relationships and compare groups:

Children's use of mathematical language to express quantitative relationships and compare groups was demonstrated during the FDO and RCA. Use of this type of language was very limited by children in the "less successful" group. Not only did children in the "more successful" group use mathematical language more frequently, but the use was also more sophisticated.

A child in the "less successful" group was observed to use mathematical language once during the FDO. While eating dinner the child finished his rice and told his mother that he wanted "more".

In contrast, children in the "more successful" group used mathematical language frequently to make comparisons. One child in the "more successful" group explained the difference in sizes between the bowls that she and her younger sister were using for their cereal as, "My bowl is big, hers is small." Another child demonstrated understanding of superlatives during the RCA. When asked which group of items had more, she asked, "You mean the most?" Also during the RCA another child in the "more successful" group explained that one group of items had “a lot” in comparison to the other. When asked to compare two groups of items, another child in the “more successful” group used a number word in her comparison to demonstrate that one had more. She explained the difference between the two groups as “10 and nothing.”

The sign “beat” was also used repeatedly by children in the “more successful” group to comment on relative differences between concepts. One child in the “more successful” group used this sign in reference to speed while playing with his mother. He set his cars up faster and told his mother, “I beat you.” A child in the “more successful” group also used this sign to compare quantities. While looking through a hidden picture book with the researcher, the child set up a game during which he and the researcher would take turns predicting what was under the flap. When the score was 2 to 0 the child announced, “I beat you!”

Geometry and Spatial Sense

As demonstrated in Table 4-21, children in the “less successful” group were observed to use concepts related to *geometry and spatial sense* more frequently than children in the “more successful” group. A possible explanation for this is that, while completing the sorting activities (i.e., PCA, RCA), the adult may have prompted a reluctant child by asking what shape a specific item was. Since children in the “more successful” group made comparisons/sorted items more independently, the concept of shapes did not present itself as frequently. As reported previously, at the .05 alpha level, the overall difference in quantity of use of concepts related to *geometry and spatial sense* between the “more successful” and “less successful” groups was not significant (p=.214).

Table 4-21: Geometry and spatial sense, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	0	0	0
FDO	5	1	6
PCA	0	4	4
RCA	13	25	38
Total	18	30	48

When use of concepts in this area was analyzed qualitatively, children in both groups were observed to use *geometry and spatial sense* concepts for the following purposes: to compare shapes; to label shapes; and to reference spatial location. The number of times each child was observed to use each of these themes is reported in Table 4-22. Since, specific episodes that were coded as demonstrating knowledge in the *geometry and spatial sense* were classified as belonging to more than one of the themes recorded in Table 4-22, the numbers in the "total" rows of Table 4-21 (18, 30) and Table 4-22 (23, 36) do not match.

Table 4-22: Geometry and spatial sense themes, by child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Label shapes	2	3	2	**7**	7	2	9	**18**
Compare shapes	4	6	4	**14**	5	3	4	**12**
Reference spatial location	2	0	0	**2**	3	0	3	**6**
Total	8	9	6	**23**	15	5	16	**36**

An independent-samples t-test was conducted to compare children in each of the two groups on their use of the themes related to *geometry and spatial sense*. At the .05 alpha level, there was no significant difference in the total number of times each theme was used by children in the two groups (labeling shapes: p=.157; comparing shapes: p=.492) making reference to spatial location: p=.329).

Labeling shapes:

Children in both groups were observed to label shapes during the RCA. Children in the "less successful" group were all observed to label the "star" and "heart" buttons by shape. One child in the "less successful" group also successfully labeled a "circle", "square", and "triangle." Another child in the "less successful" group demonstrated an ability to create groups matched by shape. When asked why the shapes were together, however, she was unable to explain her arrangement other than to say, "They're a group." When asked to label a specific shape (i.e., triangle), she responded, "That's a square."

Children in the "more successful" group labeled all shapes used during the RCA: "hearts," "flowers," "stars," "circles," "squares," "triangles," and "rectangles". A "curved" shape was also used. This was labeled as a "rainbow" or "c". Children in the "more successful" group were also observed to match shapes together and offer explanations for why the shapes formed a group such as, "These are squares and these are triangles." At times these explanations were creative. For example, when one child from the "more successful" group was asked why she had two groups of rectangles (a group of small rectangles and a group of large rectangles) instead of one, she responded by putting the two groups together. The following dialogue between the child and researcher then occurred:

Researcher: They can go together?

Child: Yes.

Researcher: Why are they together now, but before they were separate?

Child: Because they're the parents [points to large rectangles].

Researcher: Oh, they're the parents, okay. *(Points to two groups of triangles)* Can these go together?

Child: No

Researcher: Why not?

Child: They don't match.

In the above example, the child appears to make use of her existing schema to explain why large and small rectangles can be in the same category. Although, using classifiers, she labeled each shape as a "large" and "small" rectangle, it is possible that she did not understand that the label "rectangle" could apply to both (the signs she used could be viewed as a physical description rather than as a shape label). However, by referencing the large rectangles as, "They're the parents" she developed an explanation for why the shapes all fit together based on what she did know. Similar to how her family fit together, even though her parents were a different size, the rectangle group could fit together.

Examples of matching and labeling shapes also occurred for children in the "more successful" group during the FDO. One child played a memory game with her mother, grandmother, and younger brother. During this game she successfully matched and labeled a variety of shapes.

Comparing shapes:

Through the act of putting shapes together, all children were observed to make comparisons between shapes during the RCA and the FDO. When children in the "less successful" group were given an assortment of shapes during the RCA and asked to create groups, most responded by creating pictures out of the shapes. Doing this requires, at minimum, an implicit awareness of the properties of shapes in order to know how and/or why one shape should be put next to another. When children in the "more successful" group were given the same task most responded by creating groups matched by either shape or color rather than by making pictures.

At a more advanced level, during the FDO, children in the "more successful" group were observed engaging in tasks such as puzzles. Doing puzzles requires at least an implicit ability to compare shapes in order to come to a conclusion regarding what shapes should be put together. Each child in the "more successful" group, who worked on a puzzle, also separated out edge pieces, indicating an ability to focus on attributes of the puzzle pieces.

Referencing spatial location:

Children in both groups were observed to reference spatial location, although this skill was demonstrated differently. Children in the "more successful" group used language purposefully to describe spatial location. For example, while playing with his mother during the FDO, one child in the "more successful" group told his mother to "line up" her favorite cars and put them over "here." The same child later explained that visiting friends lived "near here" (his house). Another child in the "more successful" group asked, "How far is it?" in reference to her family's destination while driving.

For children in the "less successful" group, language describing spatial location was used either in imitation or for clarification. For example, during the PCA, one mother asked her child, "Why are they in the circle?" in reference to items to be sorted. The child responded, "In the circle?" Another child repeated his mother's "In" when told to put red things in a bag.

Measurement

As demonstrated in Table 4-23, children in the "more successful" group used concepts related to *measurement* approximately twice as frequently as children in the "less successful" group. As reported previously, at the .05 alpha level, the overall difference in quantity of use between the groups was not significant ($\underline{p}$=.084). For both groups, the majority of the episodes of use occurred during the FDO.

Table 4-23: Measurement, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	5	4	9
FDO	24	10	34
PCA	4	2	6
RCA	0	1	1
Total	33	17	50

When use of concepts in this area was analyzed qualitatively, children in both groups were found to use *measurement* concepts for the following purposes: to reference time and sequence; to reference distance, size, or amount; and/or to talk about speed and/or weight. The number of times each child was observed to use each of these themes is reported in Table 4-24.

Table 4-24: Measurement themes, per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Reference time and sequence	5	3	10	**18**	2	5	6	**13**
Reference distance, size, or amount	2	8	2	**12**	1	0	2	**3**
Reference speed or weight	1	2	0	**3**	0	0	1	**1**
Total	8	13	12	**33**	3	5	9	**17**

An independent-samples t-test was conducted to compare total use of measurement themes by children in each group. At the .05 alpha level, there was no significant difference in the total number of times that each theme related to measurement was used by children in the "more successful" and "less successful" groups (referencing: time and sequence, $p = .526$; distance, size, or amount: $p=.223$; speed or weight: $p=.374$).

Given the small sample size ($n=6$), a large contrast would have been required for the difference to be significant; therefore, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively as reported below. The performance of children in the "more successful" and "less successful" groups is reported in terms of how use of the three themes (i.e., referencing: time and sequence; distance, size, or amount; and speed or weight) differed between children in the "more successful" and "less successful" groups.

Referencing time and sequence:

Children in both the "more successful" and "less successful" groups demonstrated the ability to reference time and sequence, although this ability was demonstrated at a more advanced level by children in the "more successful" group. During the parent interview, parents of children in both groups reported their children's developing awareness of time. Parents of children in the "less successful" group reported that their children were beginning to notice times on the clock such as "mealtimes" and "12 o'clock." They also said that their children were developing awareness of the sequence of days of the week, for example, one parent of a child in the "less successful" group reported that her child knew that Friday meant that there was no school the next day. Similarly, during the Parent-Interview, parents of children in the "more successful" group also relayed their children's understanding of time concepts. In reference to her son, one mother reported, "He knows the difference between days he goes to school and days that he's home. He gets really excited on Fridays; He'll say, 'There's no school tomorrow!

Yay!'" Another mother reported her daughter's developing understanding of time concepts as follows:

> She knows the hour. Like she can look at the clock up there and tell me that it is 8 o'clock or the digital one is more exact, so she can tell me that it's 8:30. She kind of knows routine times of the day, around when she wakes up, mealtimes…She definitely knows the days of the week, and dates, like the 10th or the 18th , she'll know. She loves calendars, the patterns and picking out dates and what we're doing on specific dates. She loves it.

As observed, one child in the "less successful" group demonstrated a more advanced understanding of temporal concepts than the other two. Interestingly, he did this with limited use of language. For example, during the FDO, this child joined his mother to make brownies. By the time he joined her, his mother had already thrown away the brownie-mix box. The child retrieved the box from the garbage and set it up near his bowl; he pointed to the pictures as he helped his mother complete each step of the brownie making process. Then, while he was mixing the brownies, the child's mother told him when it was time to stop. He looked at the clock and responded, "No, 4 wait" meaning he would stop mixing when the minute hand on the clock got to the "4" (i.e., at 10:20); a few minutes later, when his mother again told him to stop mixing, he said, "No 5 wait," meaning he would stop mixing at 10:25. This child appeared to understand that the clock held meaning in measuring time. This child also demonstrated an ability to communicate events in the recent past. During a trip to the veterinarian's office, his dog urinated on the examining room floor; the child's mother cleaned it up. When the doctor came into the room, the child went through an elaborate sign-supported gestured explanation of what his dog had done.

Children in the "more successful" group made frequent reference to past and future events. During the FDO, one child discussed plans with his mother for an upcoming birthday party and relayed a memory regarding a previous birthday during which they went on a train. This child also expressed knowledge of time as he explained a routine event, "At school, we go to the library every Tuesday." Another child in the "more successful" group was observed chatting with her grandmother during the FDO about a previous dinner time during which their routine was different. The following conversation occurred as the child was explaining her daily routine to the researcher:

Child: 3:00 come home, 7:00 am wake up, 6:00 pm eat dinner.

Grandma: You don't eat at 6:00 pm, that's late. Get home around 4:30, you eat around 5:00 pm.

Child: No, yesterday we ate at 6:00 pm, remember? We had pizza.

Grandma: Oh, you're right, yesterday was different.

This child also talked about future events such as what would happen after she graduated from kindergarten (e.g., she would go to 1st grade). Another child in the "more successful" group made reference to events that happened even before she was born. She pointed to a decorative-piece, an old-fashioned shoe, hanging on the kitchen wall and informed the researcher that, "Daddy made that a long time ago."

During the FDO, children in the "more successful" group also demonstrated interest in knowing the sequence of activities planned for the day. One child asked his mother, "What will we do today?" Another child willingly informed the researcher about the day's events upon arrival saying, "When Daddy finishes work, we will go to [cousin's] birthday party."

Children in the "more successful" group also demonstrated recognition that time could be described and measured. One child demonstrated this when she asked, "How much longer?" while she was in the car with her mother traveling to a destination. Another mother of a child in the "more successful" group also noted that her daughter was starting to use a clock as a measurement tool. She explained this as follows, "She's looking at the clock more now; she's starting to notice like bedtime. When it's 8:30, she may argue with me and tell me it's 7:30 and I'll tell her 'no, look again, it's 8:30'."

Referencing distance, size, and amount:

The measurement concepts of distance, size, and amount were used infrequently by children in the "less successful" group. During the RCA one child from the "less successful" group asked for a "big blue square." Another child was observed to describe an item as "small" during the PCA. Children in the "more successful" group made more frequent use of concepts in this area. One child in the "more successful" group demonstrated an awareness of distance during the following conversational exchange with the researcher:

Child: Will you sleep here tonight?

Researcher: No, I'll drive to New York and stay with my family.

Child: Oh, that's far.

Then, during a later conversation with the researcher, the same child explained that her cousin's house was a far drive (about 40 minutes). She also added accurately, "Not as far as New York though."

Another child in the "more successful" group expressed an awareness of relative size as she compared the sizes of earthworms while playing outside, "That one is long; this other one is kind of medium." The same child used a comparative sign marker during the FDO when she explained to her grandmother that her muscles were "bigg*er*." Another child asked for some "really big paper" so he could draw a map that included the researcher's home (in a different state) and his own.

A child in the "more successful" group was also observed to use a variety of signs to reference the concept of "big." During the RCA, she described shapes that she had previously sorted as "big rectangles" and "small rectangles" using classifiers to describe the shape and size (i.e., size and shape specifiers); she also used classifiers appropriately during the FDO to describe "big" and "small" bowls that she and her younger sister were using for breakfast. During the PCA, she used specific signs for "big" and "small" , once even using the lexicalized (i.e., fingerspelled) sign B-I-G.

During the parent interview, one mother of a child from the "more successful" group described her son's developing concept of measuring amounts. She explained that her son was, "…motivated for learning how to feed the dog. He's learned that it has to be a certain amount. You can't give the dog too much."

Referencing speed and weight:

Concepts related to speed and/or weight were used infrequently by children in both groups. During the RCA, a child in the "less successful" group said "slow" as he pointed to a toy turtle and "fast" as he pointed to a cat.

During the FDO, a child in the "more successful" group made reference to speed when she expressed her concern that her younger brother was "faster" as he completed his puzzle before she did. Another child made reference to the number on the side of his father's lawnmower and said that meant that the lawn mower went "really fast." Another child made a reference to weight when her cousin asked her to pull a wagon full of children at a birthday party. She said, "I can't because it's too heavy." Measuring weight was also used during the PCA as a child in the "more successful" group explained that two items were "heavy."

Algebraic Thinking

As demonstrated in Table 4-25, children in the "more successful" and "less successful" groups used concepts within the strand of *algebraic thinking* with approximately equivalent frequency. As reported previously, at the .05 alpha level, the overall difference in quantity of use between the groups was not significant (p=.868).

Table 4-25: Algebraic thinking, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	5	0	5
FDO	20	8	28
PCA	17	36	53
RCA	37	32	69
Total	79	76	155

Children in the "more successful" and "less successful" groups demonstrated use of concepts related to *algebraic thinking* differently. Overall, children used *algebraic thinking* for two purposes: to identify or label attributes; and to make comparisons or show relationships. Children in the "less successful" group used *algebraic thinking* more for the first purpose than for the second. Use of each of these themes related to *algebraic thinking* is reported per child in Table 4-26. Since specific episodes that were coded as demonstrating knowledge in the *algebraic thinking* strand were classified as belonging to more than one of the themes in Table 4-26, the numbers in the "total" rows of Table 4-25 (79, 76) and Table 4-26 (130, 85) do not match.

Table 4-26: Algebraic thinking themes, per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Identify or label attributes	17	24	23	**64**	28	15	18	**61**
Make comparisons/show relationships	20	25	21	**66**	11	7	6	**24**
Total	37	49	44	**130**	39	22	24	**85**

An independent-samples t-test was conducted to compare the total number of times that each theme related to *algebraic thinking* was used by children in the "more successful" and "less successful" groups. At the .05 alpha level, there was no significant difference in use of the first theme (identify or label attributes: p=.835). There was a significant difference in use of the second theme (make comparisons/show relationships: p=.003). Children in the "more successful" group (*M* = 22.00, *SD* = 2.65) used this theme more frequently than children in the "less successful" group (*M* = 8.00, *SD* = 2.65). This is consistent with findings from the BBCS-R in which children in the "more successful" group (*M* = 8.0) demonstrated an ability to make comparisons, as measured by test score on the "comparisons" subcomponent of the test, that was significantly higher than the scores of children in the "less successful" group (*M* = 3.3; p=.033).

Given the small sample size (n=6), however, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively as reported below. The performance of children in the "more successful" and "less successful" groups is reported in terms of how use of each of the three themes (i.e., identifying or labeling attributes; and making comparisons/showing relationships) differed between children in the "more successful" and "less successful" groups. While children in both groups demonstrated awareness that entities had attributes or properties, children in the "less successful" group were likely to use these attributes as labels for items, while children in the “more successful” group tended to use these attributes as “rules” for categorizing.

Identifying or labeling attributes:

Children in both the “more successful” and “less successful” groups made frequent use of the theme related to identifying and labeling attributes. During the FDO, one child in the “less successful” group demonstrated an ability to label an attribute when she announced that the “tub was dirty,” another child told his mother that a pan needed to be cleaned saying, “Go wash it, dirty.” Children in the “more successful” group also identified attributes. During lunch time, one child in the “more successful” group went around the table labeling the members of her family as “deaf”, “hearing”, or “hard-of-hearing.”

In addition to recognizing attributes, children in the “less successful” group also used them as labels for items. For example, referring to the Sierra Mist soda that he wanted, one child told his mother, “Want drink green.” Another child used attributes (i.e., the color of the plates on the dinner table) functionally to tell where everyone where to sit (e.g., “You sit green.”). In each of these situations, it appeared as though the child was viewing the attribute not as a part of the item, but rather as a label for it. Children in the “more successful” group were not observed to use attributes in this manner.

Making comparisons/ showing relationships:

Children in the “more successful” group used the theme related to making comparisons and showing relationships more frequently than did children in the “less successful” group. During participation in the PCA, children in the “less successful” group were more likely to identify and label attributes of objects than to group items according to a shared attribute. For example, one child in the “less successful” group was encouraged to identify dolls that had long hair and dolls that had short hair. She also labeled individual items as “small”, “yellow”, “noisy”, “capable of flying”, “having wheels”, “rolling”, “red”, “pink”, “blue”, “white”, and “green”, all when asked the question, “Is this (attribute) or not (attribute),” for example, “Is this small or not small?”. Similarly, during the PCA, another child in the “less successful” group identified and labeled items according to the following attributes: hard, soft, yellow, blue, purple, green, orange, big, little, red, “blue square”, and “soft red”.

In contrast, children in the “more successful” group were observed to group items according to shared attributes. During the PCA, one child in the “more successful” group created individual groups of items that shared each of the following attributes: big, small, dark, ‘funny feel’, smooth, sticky, light or bright in color, dark in color, short, long, noisy, red, and heavy. During the RCA, another child in the “more successful” group demonstrated an ability to sort shapes by color then re-sort them according to shape. When children in the “less successful” group were given the same shapes to sort, they arranged spatial configurations creating pictures out of the shapes. They seemed to view the items to be sorted independently, rather than considering the similarities among them.

Children in the “more successful” group were also observed to make comparisons during everyday life activities. At breakfast time during the FDO, one child in the “more successful” group relayed the fact that she had to, “Use this spoon with this bowl because they match” (both had yellow and black stripes). She demonstrated her knowledge that relationships could be used to make sense of the world later in the day when she came across a ladybug while playing outside. While she did not have a label for the insect, she noticed that it was red with black spots. She compared this with another entity with which she was familiar and called the bug a “strawberry.”

Children in the “more successful” group also demonstrated an ability to seek an explanation when relationships they encountered did not make sense to them. During the following conversational exchange with the researcher during the FDO, one child in the “more successful” group demonstrated her knowledge of the relationship between hearing status and language use, in addition to her ability to seek an explanation when new information did not match her current schema. This was demonstrated during the following conversation with the researcher:

Child: Are you deaf or hearing?

Researcher: Hearing.

Child: Why?

Researcher: I was born hearing. You were born deaf, I was born hearing.

Child: I thought you were deaf.

Researcher: Why?

Child: Because you sign, deaf sign.

Another child in the “more successful” group demonstrated her understanding of the relationship between wearing hearing aids and the ability to hear birds. While playing outside the child told her mother that she could hear the birds. Her mother said, “Oh, you have your hearing aid on, so you can hear the birds.” When the researcher announced that she could hear them too the child asked, “Do you have your hearing aid on?”

During the FDO, children in the “more successful” group demonstrated an ability to use sorting for real-world purposes. One example of this occurred as children separated the edges from the middle pieces while completing puzzles. A child was also observed separating clothing that went to the laundry from those that he planned to wear again. Another was observed separating groups of cars as "yours" and "mine" while playing with his mother.

Children in the "more successful" group also demonstrated an ability to make comparisons and create groups during the PCA. One child in the "more successful" group demonstrated her ability to find the relationships among items with a variety of attributes including the following: big, small, 'funny feel', smooth, sticky, bright colors, dark colors, long, short, heavy, and noisy. The majority of these attributes are relative (i.e., something is only "big" in relation to something else that is smaller in size). This child was also able to offer explanations based on her groupings. For example, when asked why a hammer was noisy she explained, "Because you bang with it."

During the RCA, when given shapes and asked to create groups, children in the "more successful" group were typically able to create groups by one attribute and regroup according to another. When given the shapes and asked to "make groups," one child in the "more successful" group started by grouping based on the attribute of shape. After sorting the shapes, the following conversation occurred between the researcher and the child:

Researcher: Tell me about these groups you have.

Child: These are like a "c" *(points to curves).*

Researcher: A "c" okay. How about these? *(points to squares)*

Child: Squares.

Researcher: What are these? *(Points to rectangles group)*

Child: Rectangles.

Researcher: Okay, what about these? *(points to two groups of triangles which are close to each other)*.

Child: Triangles.

Researcher: Are they together or separate?

Child: Separate.

Researcher: Why?

Child: *(draws out the straight line through the air that makes the right triangles different).*

When asked if the groups could be sorted a different way, the child paused for a moment, then quickly sorted the shapes by color and labeled them.

Also during the RCA, children were asked to state the "rule" by which a group of toys was defined, and to create their own groups. Children in the "more successful" group correctly labeled groups created by the researcher as "eating and drinking things," "a group of white things", and "a group of living things." Children in the "more successful" group also successfully created their own groups. Groups created by children in the "more successful" group included: "animals", "things you drive", and "things you play with outside".

Children in the "less successful" group were less likely to identify the rule for groups created by the researcher. One child in the "less successful" group was able to label one of the groups created by the researcher, "eating things." The same child was also able to create one group on his own, "creepy things."

Problem Solving

As indicated in Table 4-27, problem solving skills were demonstrated more frequently by children in the "more successful" group than by children in the "less successful" group. However, as reported previously, at the .05 alpha level, the overall difference in quantity of use between the groups was not significant (p=.131).

Table 4-27: Problem solving, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	0	0	0
FDO	11	2	13
PCA	7	0	7
RCA	13	3	16
Total	31	5	36

While the PCA and RCA were designed to provide children with problem solving opportunities, children from the "more successful" group found natural opportunities for problem solving more frequently during the FDO than did children from the "less successful" group. This frequency is reported per child in Table 4-28.

Table 4-28: Problem solving, by child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Problem solving	3	16	12	**31**	0	0	5	**5**

During the FDO, all children in the "more successful" group demonstrated an ability to solve problems that came up in their daily environments. One child in the "more successful" group showed this as he was playing outside. Family friends had brought over a riding lawn mower for the child's father to borrow. The pick-up truck that the lawn mower came off of was parked in front of his house with wooden planks that had been used to back the lawnmower off of the truck. The child examined the situation and then brought his three-wheeled bike up onto the back of the truck using the same planks. Once on the truck, he looked behind him to make sure that his wheels were lined up on the wood planks before backing the bike off of the truck. During a different situation, while playing with cars on a floor-map with his mother, the mother acted out a car accident. She said that she was stuck and could not pick the kids up from school. Offering a strategy to solve the problem, the child told her that she needed to call a tow truck.

Also during the FDO, another child in the "more successful" group was observed solving a variety of problems. At a birthday party, goodie bags were given out. A small bottle of bubbles was among the things inside. The child could not get the bottle open, so she gave it to her father to open for her. Teasing her, her father pulled on the cap the wrong way and told her it would not open. Offering a solution, the child explained, "No, you have to twist it." The father followed his daughter's advice and opened the bottle for her. At another time during the day, the same child noticed her blue camera sitting on the kitchen table. She tried it and learned that the camera did not work. She tried to fix it by banging it on the table. When this did not work she said, "Maybe the battery is in wrong." She took the battery out and put it in a different way.

Another example of problem solving for the same child occurred while she was in the car with her mother at night. It was dark out, so the mother opened the window to wave good-bye to a friend that was traveling in the car behind them as they drove off the highway. The child, who had been sleeping in the backseat, woke up when the wind came in through the open window. The following conversation then occurred between the child and her mother:

Child: What are you doing?

Mother: We're getting off, but [friend] has to continue on the highway to her house.

Child: I don't understand, turn the light on, I can't see.

The mother turned the light on in the car and repeated her statement. The child recognized that the "problem" of not being able to see could be resolved by turning on a light.

Another child in the "more successful" group also demonstrated use of problem solving skills during the FDO. While working on a puzzle, the child appeared to use a trial-and-error approach to put pieces of the puzzle together, however she used a more organized approach as she separated the edges from the center pieces. She also used a problem solving strategy to gather information later in the day. She told her mother that she wanted to play outside. Her mother said no because it was wet out. Not wanting to accept this, the child gathered information to solve the problem of her mother's negative response. The child went to look outside and then said, "No it's not, I looked."

Only one child in the "less successful" group demonstrated problem-solving behavior in a naturalistic environment. While making brownies, this child explained to his mother that she could solve the problem of a dirty dish by washing it. He also used problem-solving behavior as he retrieved the empty brownie-mix box from the garbage while making brownies so that he could follow the picture directions.

Both the PCA and RCA were structured activities that were designed to put children in situations that required them to solve problems. As described in the section on *algebraic thinking*, children in the "more successful" group were more successful at solving these problems than children in the "less successful" group.

4.2.2.2 Personal and Social Awareness Concepts

Children's use of basic concepts related to inter-personal awareness was examined in two areas: *personal awareness*; and *social awareness*. Children's use of these concepts was demonstrated throughout the FDO, PCA, and RCA.

Personal Awareness

As demonstrated in Table 4-29, children in the "more successful" and "less successful" groups demonstrated approximately equivalent use of concepts related to *personal awareness*.

As reported previously, at the .05 alpha level, the overall difference in quantity of use between the groups was not significant (p=.276).

Table 4-29: Personal awareness, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	11	4	15
FDO	67	77	144
PCA	3	14	17
RCA	2	9	11
Total	83	104	187

As demonstrated in Figure 4-30, children were found to use *personal awareness* concepts for two purposes: to express awareness of themselves as individuals; and to demonstrate their independence. The quantity of use of each theme, per child, is indicated in Table 4-30.

There are two reasons why the numbers in the "total" rows of Table 4-29 and Table 4-30 do not match: First, specific episodes coded as *personal awareness* were classified as more than one of the themes in Table 4-30; second, other specific episodes coded as *personal awareness* did not occur frequently enough to establish a theme.

Table 4-30: Personal awareness themes, per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Awareness of self as individual	22	13	10	**45**	23	7	21	**51**
Demonstrate independence	25	7	12	**44**	9	19	18	**46**
Total	47	20	22	**89**	32	26	39	**97**

An independent-samples t-test was conducted to compare total uses of themes related to *personal awareness* by children in the "more successful" and "less successful" groups. At the .05 alpha level, there was no significant difference in the total number of uses of themes related to *personal awareness* by children in the two groups (awareness of self as individual: p=.763; demonstration of independence: p=.920).

Given the small sample (n=6), however, a large contrast would have been required for the difference to be significant; therefore, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively, as reported below. The performance of children in the "more successful" and "less successful" groups is reported in terms of how the use of each theme related to *personal awareness* (i.e., awareness of self as an individual; demonstration of independence) differed between children in the "more successful" and "less successful" groups.

Awareness of self as an individual:

Children in both the "more successful" and "less successful" groups demonstrated awareness of themselves as individuals, although they expressed this awareness differently. Overall, children in the "more successful" group were more likely to demonstrate *personal awareness* by using language to communicate their likes, dislikes, wants, and needs. An example of this occurred during the FDO when one child in the "more successful" group told her mother that she wanted to go outside to play. Another child expressed her displeasure at the hairstyle her mother chose for her, explaining that she preferred for her hair to be done to look like a character on the jacket of a favorite video.

Children in the "less successful" group were more likely to demonstrate *personal awareness* by choosing their own activities, or using physical actions to get what they wanted or needed. Children in the "less successful" group were more likely to communicate their likes, dislikes, wants, needs, thoughts and feelings by using pointing, gestures, and/or actions. For example, during the FDO when one child in the "less successful" group did not want his cochlear implant put on he yelled "NO!" and ran to the other end of the house. When another child in the "less successful" group was told that he could not play on his computer, he communicated his displeasure by throwing a temper tantrum that included taking batteries out of the television's remote control and throwing them.

Demonstrating independence:

Demonstrating independence included an ability to be self-reliant in self-care activities and to choose activities independently. With the exception of one child in the "less successful" group, all children demonstrated independence in the areas of self-care activities. Five of the 6 children dressed themselves, brushed their teeth, and ate independently. During the FDO, children in the "less successful" group were observed to demonstrate more independence as they were responsible for choosing their own activities. Parents of children in the "more successful" group were more likely to suggest activities for their children to take part in.

Social Awareness:

As demonstrated in Table 4-31, children in the "more successful" group used concepts related to *social awareness* more than three times as frequently as children in the "less successful" group. Despite this difference in quantity, as reported previously, at the .05 alpha level, the overall difference in quantity of use between children in the "more successful" and "less successful" groups was not significant (p=.062).

Table 4-31: Social awareness, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	10	10	20
FDO	96	34	130
PCA	3	2	5
RCA	3	2	5
Total	112	48	160

Three themes were found regarding children's demonstrated *social awareness*. These themes included the ability to: interact appropriately with others; follow rules and directions, and seek information. In Table 4-32 the number of times each of these themes was used by each child is reported. Since specific episodes coded as demonstrating knowledge in the *social awareness* strand were classified as belonging to more than one of the themes in Table 4-32, the numbers in the "total" rows of Table 4-31 (112, 48) and Table 4-32 (158, 64) do not match.

Table 4-32: Social awareness themes, by child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Interacts appropriately	29	33	29	**91**	15	5	7	**27**
Follows rules/directions	8	7	14	**29**	4	9	4	**17**
Seeks information	20	14	4	**38**	12	6	2	**20**
Total	57	54	47	**158**	31	20	13	**64**

An independent-samples t-test was conducted to compare total uses of themes related to *social awareness* by children in the "more successful" and "less successful" groups. The difference between the ability of children in the "more successful" and "less successful" groups to "interact appropriately" was significant at the .05 alpha level (p=.003). Children in the "more successful" group (M = 30.33, SD = 9.00) demonstrated use of this theme more frequently than children in the “less successful” group (*M* = 9.00, *SD* = 5.23). There was no significant difference in use of the other two themes related to *social awareness* (follows rules/directions: p=.219; seeks information: p=.336).

Given the small sample size (n=6) however, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively, as reported below. The performance of children in the “more successful” and “less successful” groups is reported in terms of how the three themes related to *social awareness* (i.e., ability to: interact appropriately; follow rules/directions; and seek information) differed between children in the “more successful” and “less successful” groups.

Ability to interact appropriately with others:

An ability to interact appropriately with others included playing cooperatively, taking turns, sharing, and/or engaging in playful teasing. Children in the “more successful” group were observed to interact appropriately with others the majority of the time. Children were observed to play games in which they willingly took turns, shared candy and toys with friends and/or siblings, and engaged in teasing routines with family members.

Children in the “less successful” group interacted with others less frequently than children in the “more successful” group. Even when they were involved in the same activities as others, they appeared to be acting independently. For example, during the FDO a child in the “less successful” group was at the playground with his brother. The pair was observed playing on the swings, slide, and monkey bars at the same time, yet they did not interact during these activities. In contrast, a child in the “more successful” group was observed playing multiple interactive games with his younger sister. This was also observed during the RCA, children in the “more successful” group were more likely to interact appropriately with the researcher.

Children in the “less successful” group were more likely to leave the table and/or change the topic of discussion.

Ability to follow rules and directions:

Children in the “more successful” group were more likely to follow rules and directions than children in the “less successful” group. One typical example of this for a child in the “more successful” group occurred when the child told his father that he wanted to go outside. His father reminded him, “You know the rules. You need your socks, shoes, and coat, before you can go out.” Not wanting to do so, the child decided to stay inside. In the homes of the “more successful” children there seemed to be more rules established for children to follow than for children in the “less successful” group. For example, a typical rule of the home for children in the “more successful” group was that eating was allowed in the kitchen and nowhere else. In contrast, children in the “less successful” group were observed eating in various rooms of the house.

During the RCA, children in the “more successful” group willingly followed the directions established by the researcher. Children in the “less successful” group were more likely to try changing the activity or interact inappropriately with the materials; for example, by turning the activity into a speech exercise, or by putting the materials in their mouths.

Similar behavior was observed during the PCA. For children in the “more successful” group, taking part in a structured activity did not appear to be out of the ordinary. Children in the “less successful” group demonstrated difficulty focusing on the task and frequently left the table before the task was completed.

Ability to seek information:

As Table 4-33 indicates, children in the "more successful" and "less successful" group were observed to ask approximately the same quantity of questions.

Table 4-33: Questions children asked

Instrument	*More successful*	*Less successful*	*Total*
FDO	35	4	39
PCA	1	22	23
RCA	11	5	16
Total	47	31	78

In Table 4-34, the number of questions asked by each child is recorded.

Table 4-34: Questions asked per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Number of questions asked	25	17	5	**47**	20	10	1	**31**

An independent-samples t-test was conducted to compare the quantity of questions asked by children in the "more successful" and "less successful" groups. At the .05 alpha level, the difference between the groups was not significant (p=.541).

Given the small sample size (n=6), however, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively in terms of the type and purpose of the questions that children asked. Questions asked by children in the "more successful" group appeared to serve an instrumental and heuristic purpose. Through the questions they asked, children in the "more successful" group demonstrated curiosity and sought information. Typical questions asked by children in the "more successful" group included, "Are you deaf or hearing? Why?"; "What's it mean?" (in reference to a parent's fingerspelled word) and, "How far is it?" All three children in the "more successful" group inquired as to the researcher's purpose for being in their home during the FDO, usually asking, "Why are you here?" No child in the "less successful" group inquired as to the researcher's purpose in visiting his/her home.

For children in the "less successful" group, the majority of questions asked appeared to be for purposes of clarification, for example, "In the circle?" (repeated parent's question during the PCA); and "What did you say?" or to achieve a yes/no response, "You like it?"

4.2.2.3 Early Literacy

As demonstrate in Table 4-35, children in the "more successful" group demonstrated more frequent use of concepts related to *early literacy* than did children in the "less successful" group. As reported previously, at the .05 alpha level the difference in quantity of use of concepts related to *early literacy* was not significant between the two groups (p=.399).

Table 4-35: Early literacy, Episodes of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	5	3	8
FDO	22	15	37
PCA	1	0	1
RCA	1	0	1
Total	29	18	47

Three themes were found regarding children's demonstrated use of *early literacy*. These themes were: spelling/reading words; interacting with print; and writing. In Table 4-36 the number of times each of these themes was used by each child is reported.

The numbers in the "total" rows in Table 4-35 (29, 18) and Table 4-36 (33, 16) do not match for two reasons: first, specific episodes coded as demonstrating knowledge in the *early literacy* strand were classified as belonging to more than one of the themes in Table 4-36; second, other specific episodes coded for *early literacy* did not occur frequently enough to establish a theme.

Table 4-36: Early literacy themes, per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Spell/read words	7	4	6	**17**	4	0	1	**5**
Interact with print	7	0	4	**11**	4	2	0	**6**
Write	2	2	1	**5**	2	3	0	**5**
Total	16	6	11	**33**	10	5	1	**16**

An independent-samples t-test was conducted to compare the total number of times that each theme related to *early literacy* was used by children in the "more successful" and "less successful" groups. At the .05 alpha level, there was no significant difference in the total number of times each theme was used (spell/read words: p=.055; interact with print: p=.515; write: p=1.0).

Given the small sample size (n=6) however, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively, as reported below. The performance of children in the "more successful" and "less successful" groups is reported in terms of how use of the three themes (i.e., spelling/reading words; interacting with print; and writing) differed between children in the “more successful” and “less successful” groups.

Spelling/reading words:

Children in both the “more successful” and “less successful” groups were observed to spell and read words, or at least make attempts at doing so. Children in the “less successful” group were observed to use letter recognition and invented spelling during the FDO. One child in the “less successful” group saw familiar characters from the movie *Toy Story* while she was looking through a catalog. She spelled their names using invented spelling (e.g., “ELB”). The same child also demonstrated letter recognition during a walk through her neighborhood. She walked past a carpet store with her mother. The store had a sign out front that said “Carpet Sale.” The child looked at the letters on the sign and spelled C-A-R-P-E-T S-A-L-E. Another child in the “less successful” group used invented spelling as he looked through a photo album that included pictures of his horse “Sugar.” He used invented spelling to label the horse by name.

Children in the “more successful” group appeared to use spelling and reading words more meaningfully. While the mother of one child from the “more successful” group was having a conversation with the researcher she spelled the word “daycare”. The child, who was intently watching the conversation, interrupted his mother and asked her what the fingerspelled word meant. Children in the “more successful” group were also observed to spell: names of people, vocabulary words, and words for which they did not know the sign (e.g., tattoo) all accurately enough to be understood.

Interacting with print:

Children in the “more successful” and “less successful” groups were observed interacting with print; however, for children in the “more successful” group, this interaction appeared to be more meaningful. One child in the “more successful” group was observed interacting with print as he reviewed his mother’s shopping list and asked her what the words that he could not read meant (e.g., “soft potato”). During the FDO, children in the “more successful” group were also observed interacting with books. One child watched a story signed in ASL on videotape, as he looked through the book in print, with his family. All children in the “more successful” group were also exposed to print through captions on the television. Although no explicit attempts were made to read them during the FDO, one parent stated that her daughter was capable of reading the words on the captions to a limited extent.

Only one child in the “less successful” group was observed interacting with print. This child had a catalog of equipment, including inflatable trampolines that could be rented for parties. She carried this catalog around with her all day, occasionally pointing to print and asking her mother what it meant (e.g., “send in the clowns”).

Writing:

Although not frequent, most of the children were observed writing at some point during the FDO. The quality of the writing that was observed differed between children in the “more successful” and “less successful” groups.

Children in the “more successful” group demonstrated more independence in the writing of words. For example, a child in the “more successful” group wrote letters in the researcher’s notebook, then got her own paper and began to make a birthday card for her cousin.

Independently, she spelled “L-O-V-E Y-O-U”, fingerspelling the words prior to writing them. She asked her mother how to spell her cousin’s name then wrote this on the card as well.

The writing of children in the “less successful” group was less purposeful. One child in the “less successful” group wrote the names of people she knew in the researcher’s notebook, asking for assistance with spelling. During an arts and crafts activity with his family, another child in the “less successful” group wrote a series of letters along with the names of people in his family.

4.2.3 Section Summary:

As discussed in this section, children in both the “more successful” and “less successful” groups demonstrated an understanding of basic concepts; this understanding however appeared to be at a more advanced level for children in the “more successful” group. Children from this group achieved scores of “average” to “advanced” across all basic concepts measured by the BBCS-R while children from the “less successful” group achieved scores of “delayed” to “very delayed” across all concepts measured by the test. When understanding of basic concepts was observed within a naturalistic environment, this relationship held; children from the “more successful” group used language to demonstrate their understanding of basic concepts and relationships throughout daily activities and structured tasks while, with less developed language skills, children in the “less successful” group were less able to demonstrate their understanding of basic concepts, thereby indicating the possibility that children with lower levels of achievement in the area of mathematics may also have a weaker understanding of basic concepts. What emerges from this finding is a need to consider the environment in which early, foundational knowledge develops. In the next section, the home environments of young deaf children will be considered through analysis of the mediation techniques used by parents of children in the "more successful" and "less successful" groups.

4.3 MEDIATION TECHNIQUES USED IN THE HOME

Mediation techniques were coded using the coding scheme found in Appendix D. Three dimensions of mediation were examined: *Intentionality/Reciprocity*, *Transcendence*, and *Meaning*. *Intentionality/Reciprocity* refers to the manner in which a mediator sets up a learning experience. An effective mediator will monitor the environment or learning situation in a manner so as to concretely maximize learning (Feuerstein, 1997). The critical feature of the *Intentionality/Reciprocity* dimension is an environment that maximizes learning. As described in the coding sheet in Appendix D, adults may maximize learning for their children by: establishing learning opportunities in which children can develop independence and self-sufficiency; acting in a way to consciously modify children's behavior; making conscious use of materials and/or environmental tools to enhance children's learning and cultural understanding; initiating conversations that are appealing to young children; initiating learning activities, events, and experiences that anticipate learning; establishing schedules and routines that communicate information regarding family beliefs, rules, traditions, and values; communicating the expectation that children will learn cultural values, appropriate behavior, and use of social mores; being responsive to child's lead during interaction; soliciting child's involvement in activities and conversations; and/or expressing interest and pride in children's accomplishments.

Transcendence refers to the potential for the current learning experience to go beyond the immediate situation. The effective mediator will provide information explaining why an event occurs or why a particular experience is necessary. The critical feature of *Transcendence* is the explanations that mediators offer. High quality explanations place actions or events within a larger context, and/or establish causal relationships between events, thereby encouraging children to notice when and why things happen.

The third dimension is *Meaning*. Effective mediators will encourage children to apply their concepts or ideas to their observations. The critical feature of this dimension is the questions mediators ask to stimulate children's thinking. High quality questions ask children: to solve problems; answer questions; use logical thinking; refer to past experience; and/or project into an abstract future event, thereby encouraging children to apply their knowledge of the world to explain why things happen the way they do.

The three dimensions of mediation are interdependently related with the deepest layer, *Meaning*, including characteristics of the other two. Since it is difficult to consider each dimension exclusively, for the purpose of coding, each dimension was examined according to its critical feature: the environment for *Intentionality/Reciprocity*; explanations for *Transcendence*, and questions asked for *Meaning*.

This section will begin with a brief review of the instruments that were used to collect data on mediation techniques used by the adults raising the six children who participated in Level 2 of this study. Since the essential ingredient of any mediated learning experience is interaction, the degree to which adults interacted with participants in their home/family environments will be discussed next. This will be followed by a discussion of several themes that emerged from the data in each of the three dimensions in each group of participants (i.e., "more successful" and "less successful").

4.3.1 Instruments

Three instruments were used to collect data on the mediation techniques used by families with young deaf children: a Full-Day Observation (FDO); Parent-Interview; and a Parent-Child Activity (PCA). For the FDO, the researcher arrived at the child's house at approximately the time the child woke up in the morning and stayed until approximately the time when s/he went to bed at night. The researcher observed family interaction during the entire day, following the child during his/her daily activities. During this time, the researcher recorded field notes in a small notebook regarding child activities and interaction with anyone in the environment. To the greatest extent possible, the researcher remained a non-participant observer throughout the day spent with the family. The purpose of the Parent-Interview was: to obtain information regarding family functioning and daily interaction that might not have been available through observation alone; and to understand families' perspectives regarding the role that parents and the home environment played in encouraging children's learning. The purpose of the PCA was to provide all families with a similar, structured, opportunity to demonstrate their skills in providing mediating learning experiences for their children.

4.3.2 Interaction Time

In order for a mediated learning experience to occur, the child must be interacting with the mediator. Within the home/family environment, this occurred to varying degrees for the children who participated in Level 2 of this study. In addition to field notes, in order to record interaction time, the researcher kept a record of what the child was doing every ten minutes using the recording form found in Appendix E. Every tenth minute throughout the FDO, the child's activity was recorded as well as who, if anyone, s/he was interacting with.

"Alone" was defined as not interacting with anyone. Therefore, although the child may have been in the same room with another adult, if no interaction was occurring, this was recorded as "alone." As Table 4-37 indicates, represented by time recorded in 10 minute intervals, children in the "less successful" group spent a greater percentage of time alone during the FDO (51%) than did children in the "more successful" group (13%).

Table 4-37: Percent of time spent interacting with others

Individual with whom child was interacting	*More successful*	*Less successful*
An adult	75%	46%
Another child	13%	4%
Alone	13%	51%

An independent-samples t-test was conducted to compare the percentage of time that children in the "more successful" and "less successful" groups spent alone. At the .01 alpha level, there was a significant difference in the percentage of time that children in the "more successful" (M = 13%, SD = .065) and "less successful" (M = 51%, SD = .075) groups spent alone (p=.003). Children in the "less successful" group spent a significantly greater proportion of their day alone. It should be noted, however, that all three children in the "more successful" group had siblings while two of the three children in the "less successful" group did not. Nevertheless, children in the "more successful" group only spent 13% of the FDO interacting with another child without an adult also involved in the interaction.

4.3.3 Three Dimensions: Critical Differences

As reported in Table 4-38, the overall quantity of events of observed use of mediation techniques was greater for parents of children in the "more successful" group than for parents of children in the "less successful" group.

Table 4-38: Mediation, Events of observed use by group

	More Successful	*Less Successful*	*Total*
Intentionality & Reciprocity: Environment	88	55	143
Transcendence: Explanations	92	43	135
Meaning: Questions asked	92	108	200
Total	272	206	478

The quantity of events of observed use of mediation techniques, per child, is reported in Table 4-39.

Table 4-39: Mediation, Events of observed use per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Intentionality & Reciprocity: Environment	35	27	26	**88**	17	19	19	**55**
Transcendence: Explanations	43	21	28	**92**	10	17	16	**43**
Meaning: Questions asked	2	57	33	**92**	84	14	10	**108**
Total	80	105	87	**272**	111	50	45	**206**

An independent-samples t-test was conducted to compare totals on the quantity of use of each dimension of mediation (*Intentionality and Reciprocity*; *Transcendence*; and *Meaning*). At the .05 alpha level the difference between the groups was not significant for two of the three dimensions (transcendence, p=.076; meaning, p=.862). The difference between the groups was significant for the dimension of *Intentionality and Reciprocity* (p=.020). Parents of children in the "more successful" group exhibited greater levels of use of *Intentionality and Reciprocity* (*M* = 29.33, *SD* = 4.933) than did parents of children in the "less successful" group (*M* = 18.33, *SD* = 1.155).

Given the small sample size (n=6) however, statistical findings must be accepted with caution. For this reason, findings were also analyzed qualitatively as reported in the sections that follow. Throughout all three dimensions (*Intentionality & Reciprocity*, *Transcendence*, and *Meaning*), differences were observed in the types of mediated interactions experienced by children in the "more successful" and "less successful" groups. These differences will be discussed in the sub-sections that follow.

4.3.3.1 Intentionality/Reciprocity

The dimension of *Intentionality/Reciprocity* refers to the manner in which a mediator sets up a learning experience. An effective mediator will monitor the environment or learning situation in a way so as to concretely maximize opportunities for learning. As described in the coding sheet in Appendix D, adults may maximize learning opportunities by: establishing learning opportunities in which children can develop independence and self-sufficiency; acting in a way to consciously modify children's behavior; making conscious use of materials and/or environmental tools to enhance children's learning and cultural understanding; initiating conversations that are appealing to young children; initiating learning activities, events, and experiences that anticipate learning; establishing schedules and routines that communicate information regarding family beliefs, rules, traditions, and values; communicating the expectation that children will learn cultural values, appropriate behavior, and use of social mores; being responsive to children's lead during interaction; soliciting children's involvement in activities and/or conversations; and/or expressing interest and pride in children's accomplishments.

As stated previously, at the .05 alpha level, parents of children in the "more successful" group exhibited significantly greater levels of use of *Intentionality and Reciprocity* (*M* = 29.33; *SD* = 4.933) than did parents of children in the "less successful" group (*M* = 18.33; *SD* = 1.155). This dimension was also analyzed qualitatively. Four themes were found to emerge from study data to describe parents' use of the *Intentionality/Reciprocity* dimension: Cultural Beliefs and Expectations; Daily Routines; Preparation for the Non-routine; and Creating Environments for Learning. The quantity of times each of these themes occurred per child is reported in Table 4-40.

Table 4-40: Themes related to Intentionality and Reciprocity

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Cultural Beliefs & Expectations	8	7	4	**19**	4	4	8	**16**
Preparation for the Non-Routine	3	3	1	**7**	2	2	0	**4**
Daily Routines	4	4	4	**12**	5	1	3	**9**
Creating Environments for Learning	20	13	17	**50**	6	12	8	**26**
Total	35	27	26	**88**	17	19	19	**55**

An independent-samples t-test was conducted to compare the total use of themes related to *Intentionality and Reciprocity* by parents of children in the “more successful” and “less successful” groups. At the .05 alpha level, there was no significant difference between the groups for three out of the four themes (cultural beliefs and expectations: p=.607; preparation for the non-routine: p=.349; daily routines: p=.435). One theme, “creating environments for learning” was significant (p=.041). Parents of children in the “more successful” group (*M* = 16.67, *SD* = 3.51) demonstrated greater use of themes related to creating environments for learning than parents of children in the “less successful” group (*M* = 8.67, *SD* = 3.06).

Given the small sample (n=6) however, these statistical findings must be accepted with caution. For this reason, the data were further analyzed qualitatively, as reported below. Parental mediation techniques used by children in the “more successful” and “less successful” groups is reported in terms of how use of each of the four themes (i.e., cultural beliefs and expectations, daily routines, preparation for the non-routine, and creating environments for learning) differed in the homes of children in the “more successful” group and “less successful” groups. Following a discussion of these four themes, the PCA will be discussed in terms of a comparison between the ways that children in the “more successful” and “less successful” groups experienced this activity.

Cultural Beliefs and Expectations

As reported previously, in terms of the quantity of occurrences observed to convey cultural beliefs and expectations, the difference between the “more successful” and “less successful” groups was not significant at the .05 alpha level (p=.607). For children in both groups, parents’ cultural beliefs and expectations were mediated to children most clearly through the manner in which rules and responsibilities were delineated, how discipline was handled, and in general, parents' beliefs about raising a deaf child. Qualitatively however, differences were found in the manner through which parents of children in the "more successful" and "less successful" groups mediated cultural beliefs and expectations to their children.

Parents of children in the "more successful" group frequently reminded their children about household rules and responsibilities. When one child in the "more successful" group tried to bring a drink into his bedroom, his mother reminded him of the rule that food and drink could only be consumed in the kitchen. Later in the day, the same child brought a drink outside of the kitchen anyway, albeit in a covered cup. His mother asked him, "Did Dad say that was okay." The child responded, "Dad didn't see." While his mother did not deny him the drink, she reminded him of his responsibility in accepting the consequences for his actions telling him, "Okay, but it's you're responsibility. You know if it spills on the carpet Dad will get mad at you."

Another child from the "more successful" group was reminded of the rules at a party when she tried to leave the table a few times while eating. Her mother reminded her, "The rules here are the same as at home; you sit when you eat." Later in the day the same mother required her daughter, when she tried to blame her little sister for a ripped birthday hat, to take responsibility for her actions saying, "The rip was your fault, don't blame your sister." Reminders of the rules also occurred in the home of the third child in the "more successful" group, as observed when a mother told her 2-year-old daughter, "You eat in the kitchen" when she tried to bring her peanut butter sandwich into the living room.

When misbehavior occurred for children in the "more successful" group, it was handled calmly and respectfully using language. When a child climbed on a stair railing, his mother firmly reminded him, "No, Dad said no." When the child got off of the railing his mother said, “Thank you for listening.” There was also evidence of this calm yet firm approach to discipline in the home of another child from the “more successful” group. The child was lying on the kitchen floor drawing a picture for her cousin. Her 2-year-old sister came over and walked on the picture. The child hit her. The following dialogue then took place between the child and her mother:

Mother: No hitting.

Child: She stepped on my picture.

Mother: She’s a baby; she doesn’t understand.

When the 2-year-old stepped on the picture again, the mother went over to the young child and firmly said, “No.” Another example of how this mother handled discipline occurred when her 2-year-old daughter was playing with a pen that had a heart on a spring at one end. The child was waving the pen around. The mother came over to her and said, “Don’t wave it you’ll hurt your eye.” When the child continued to wave the pen around anyway, the mother took the pen away giving the child a kiss at the same time. This mother, while concerned about her child’s safety, also recognized that the explanation offered was beyond the young child’s comprehension.

Rules and responsibilities were less clearly and less frequently conveyed in the homes of children in the “less successful” group. During the Parent-Interview, one mother relayed a recent conversation in which she and her daughter discussed the need to behave on the school bus. A second event occurred when a mother, after giving her sons popsicles, reminded her children to, “Make sure that the paper from the ice goes in the trash.” Beyond these two occurrences, no other reminders regarding rules and responsibilities were observed in the homes of children in the “less successful” group.

When misbehavior occurred for children in the “less successful” group, discipline was handled differently than what was observed for children in the “more successful” group. At one point during the FDO, one child’s younger brother came into the bedroom with a bowl of potato chips. As the child took one, his younger brother objected saying, “Hey!” as he hit his brother on the head. The child hit him back. The younger brother then told his father, “He hit me!” The father replied, “Well you hit him.”

A similar tolerance of hitting done in retribution was demonstrated in the home of another child from the “less successful” group. In the car, while traveling home from the veterinarian’s office, the child was arguing with his mother who was attempting to get him to sit. In the process, the child hit her. She hit him back saying, “What you do to me, I’m gonna do back.”

In terms of learning outside of the school environment, parents of children in the “more successful” and “less successful” groups appeared to have different perspectives on the role played by the family. Parents of children in the “more successful” group expressed an overall belief that learning occurred naturally. The mother of one child explained, “We just take advantage of what’s happening.” She went on to explain that her son was, “motivated and curious,” and that he just “likes learning how to do things.” Another mother expressed a similar belief when she said that, “We’re Deaf, a Deaf family; it’s just natural for us. The kids are third generation Deaf. Learning is natural, it just happens.” Similarly, another mother explained, “My family is Deaf so, you know, it’s just natural exposure, that’s how they learn. We just constantly throw new information at them, words and what they mean, or interesting things we notice. It’s just exposure, learning and encouraging their motivation.”

For parents of children in the "less successful" group, learning seemed to take a more conscious effort with managing behavior playing a central role. The parents of one child explained how they used rewards to encourage learning at home:

> We reward them. We use snacks, or whatever they like, free time to do what they want to do. For [child], he likes stickers and cars, sugar, anything that has sugar in it. Something else we do is 'first you do this and then…' cause and effect, that's kind of hard because you have to show him first, but after the repeatedness of it then he picks up and he understands it.

Parents of another child in the "less successful" group stated that:

> …as for learning his responsibilities for taking care of his animals, we do the same thing you would do with any other kid. I mean you encourage him, if he doesn't do it right you explain what he did wrong and if he's completely wrong then he gets his discipline.

The mother of another child in the "less successful" group expressed the importance of positive reinforcement in encouraging her daughter's learning. She explained, "I always tell her 'good job, you did a very good job.' She'll say, 'Mommy I can't do this' and I'll say 'Yes you can, you can do anything.' That encourages her, I see that."

Parents' beliefs about the challenges involved with raising a deaf child were also different. Parents of children in the "more successful" group reported that deafness was "natural" and "normal". As such, as natural learning opportunities arose, they were used as a means of mediating tenets of Deaf culture. For example, while one child in the "more successful" group was working on vocabulary words with her mother, the child started signing the words very loosely. Not accepting this, her mother stated, "Come on, no sloppy signing, sit up." Later in the day, the child was sitting outside with her family and chatting with her grandmother. The grandmother asked, "What's up," using a sign that in Deaf culture means, "How are you?" Outside of Deaf culture, a typical response to this statement is "nothing". When the child replied this way, saying "nothing," her grandmother replied, "That's not how you respond to that question. Tell me about Friday, what did you do at school on Friday?"

Raising a deaf child appeared to be a challenge for parents of children in the "less successful" group. Communication, and how this related to safety, seemed to be the biggest concern. The mother of one child explained, "I worry sometimes when…I'm outside with her that sometimes she'll run, and I'll get nervous that she'll go too far where she doesn't hear me, even if she's five feet in front of me. I'll get nervous that she'll go out in the street somewhere." Parents of another child from the "less successful" group also mentioned this problem. They explained it as follows, "…we need to keep a sharper eye on him than let's say my sister across the road has to keep on her kids. Because, if one of them disappears she sticks her head out the window and bellows and they either answer or come running. We can't do that."

The family of another child in the "less successful" group did not acknowledge any difficulties regarding the ramifications of their son's hearing loss. In describing how hearing loss influenced the daily functioning of their family, the parents replied, "No one in this family really treats him like a deaf person. I just want to treat him like everyone else. I mean, I'll use sign language for communication, but no one treats him different, it doesn't have an effect on him."

The "curriculum" for learning in the home environment varied for children in the "more successful" and "less successful" groups as well. During the Parent-Interview, one mother of a child in the "more successful" group expressed her belief that her daughter's personality was the most important thing she learned at home. In addition, she also felt that her daughter learned about, "…self-identity, knowing herself as a Deaf person...[and] compassion." The mother of another child in the "more successful" group stressed the importance of her children learning, "…about assertiveness and how to advocate for themselves." She also felt it was important that her children learn, "…about being a part of a family." This mother also saw value in enhancing her children's vocabulary. She described this belief as, "…in general I think the vocabulary is really important. I have around 100 vocabulary words I want them to learn before the Fall. If they learn the vocabulary here, then when they arrive at school they'll already know." During the FDO, this mother was observed working on these vocabulary words with her children.

In her description of what her son learns at home, one mother of a child in the "more successful" group stressed the importance of household tasks and developing his responsibility in caring for the home environment. She explained some of these responsibilities as follows:

> He's learned about cleaning up. He knows he can't leave his toys laying around, they have to be picked up because if they are just laying around someone could trip over them. He's learned about the laundry. He knows to put his dirty clothes in the hamper in his room, then to bring them down to the laundry room when the bag is full. Also, he knows to sort the clothes by color before we wash them. He started that in the old house, but he's really getting better at it now.

During the FDO this child was observed helping his mother with tasks around the house including making his bed, sorting and folding laundry, loading and unloading the dishwasher, and cleaning up his room.

Children's responsibility for helping to care for the home environment was also evident in the homes of the other two children in the "more successful" group. One mother explained that her daughter helped her with folding clothes, cleaning up, and putting things away. During the FDO, this child did help around the house in various ways including bringing her dishes to the sink after eating and helping outside with yard work. This mother's belief that her children develop responsibility for cleaning up was particularly evident at one point during the morning of the FDO. The child and her brother were working on puzzles. When the brother finished his puzzle he slid it off of the table and onto the floor. The child moved to help him clean it up, but her mother intervened calmly stating, "No, himself. He knocked it off, he can clean it up."

Another mother of a child in the "more successful" group stated during the Parent-Interview that her daughter will help around the house in small ways by cleaning up her dolls or turning the television off when asked. During the FDO this child was observed assisting around the house by setting the table for breakfast and helping her younger sister, without prompting, in a variety of ways (i.e., cleaning up when milk was spilled on the table; helping her find her shoes before leaving the house, etc.). Even the 2-year-old was observed helping around the house. She willingly went over to help her mother unload and reload the dishwasher. Children in the "more successful" group appeared to be learning that they had responsibilities in their home environments and that their input was welcomed and valued.

As expressed by parents of children in the "less successful" group, beliefs about learning at home were similar; although, during the day of observation, these beliefs were not observed in practice. During the Parent-Interview, one mother of a child in the "less successful" group said that her daughter's personality was the most important thing she learned at home. In terms of household tasks, she mentioned that her daughter will help around the house in a variety of ways. The mother described this help as follows:

> She helps me with everything. She'll help me with doing laundry, she'll try and mop, or

> she'll try and wash the dishes. I guess because it's just me and her she just does everything I do. If I'm cooking, like I'm making meatballs, I'll let her help me with the meatballs (rolling them), stuff like that, she enjoys that kind of stuff.

Although during the FDO this child was not observed to help with any household tasks, it is possible that she does at other times. During the FDO, she did make an attempt to help her mother with a task; however, her assistance was denied. The child and her mother had recently moved into a new apartment and boxes were still in the process of being put away. The mother brought a box of the child's books into the living room and began to put them away in the entertainment center. The child went over to her mother, took a few of the books out of the box and tried to put them away. Her mother intervened saying, "No, let me do it." The mother then took the books and stacked them neatly in the closet herself.

During the Parent-Interview, the parents of one child in the "less successful" group stressed "self-sufficiency" and "independence" as important values that their son learned at home. The father also stressed that they, "Focus on directions, quickly get things done, clean your room, go outside and play." In terms of helping around the house, the parents stated that, "It's a must that he clean his room. That's pretty much all the chores they have to do." In-line with his parents' comments, this child was not observed assisting in any household tasks during the FDO, nor was he observed to clean his room.

The final child in the "less successful" group lived on a farm. During the Parent-Interview, his parents stated their belief that this environment provided a wealth of learning opportunities that their son could not get in school. These learning opportunities included learning, "…the responsibility of taking care of his animals. He has a horse, a cow, and a dog." According to his parents, "feeding, care and grooming," were this child's major responsibilities.

During the FDO, however, the child was not observed partaking in any of these tasks. As for other household tasks, his parents reported that their son will “help cook” or “help set the table,” but also that it “depends on what his mood is.” The child’s parents also reported that this child:

> ……likes to run the sweeper, he helps with laundry, he helps clean up a little bit, he dusts. Another thing he likes to do is he likes to load the washer machine. He won’t sort the laundry at all, pretty much whatever gets in his arms goes into the machine.

During the FDO, this child was observed helping his mother make brownies, however he was not observed assisting with any other house-hold tasks.

In summary, while families of children in both groups mediated information regarding cultural beliefs and expectations to their children, for children in the “more successful” group there appeared to be a belief that “learning is natural” and embedded within everyday tasks and activities such as helping around the house. For children in the “less successful” group, there appeared to be more of an emphasis on managing behavior, with use of rewards and reinforcement playing a central role.

Preparation for the Non-Routine

As reported previously, in terms of the quantity of occurrences observed in which preparation for non-routine events was conveyed, the difference between the “more successful” and “less successful” groups was not significant at the .05 alpha level (p=.349). For children in both groups, non-routine events occurred. Qualitatively, however, the preparation for these events differed in the homes of children from the “more successful” and “less successful” groups.

Families of children in the “more successful” group appeared to put conscious effort into planning certain outings and preparing for them. This was particularly evident in the family of one child in the "more successful" group. During the Parent-Interview, her mother explained local excursions and vacations that the family took:

> We go to friends' houses, their cousins, we're there a lot. We go to amusement parks… We also travel a lot. We've been to Washington D.C and all different places. Recently when we went to Indiana we decided to stop at that place, you know where Flight 93 went down? In Pennsylvania? I explained to [daughter] what happened, that the plane went down because of some bad people, then she could make that connection and know where it happened… So that kind of thing. Also, this summer we'll be taking the girls to a camping park, in the country. Over 2,000 Deaf people will be there, they're coming from all over. They're going to have wonderful children's activities and everything set up there so we're really excited about that.

The value this family placed on excursions outside of the home was also evident during the FDO. Two parties and a trip to a store were planned for the day. Each trip was discussed before getting in the car. One discussion included the need to stop at the store before going to the party. On the way to the party, a discussion of who would be there occurred. A discussion later in the day prepared the child for a trip to the jewelry party that they would be attending. Prior to this final trip of the day the mother explained to her daughter that the woman hosting the party was White and that her husband was Black. This meant that their 2 daughters looked different.

Another mother of a child in the "more successful" group also saw the value of outings outside the home. During the Parent-Interview she mentioned the importance of her children learning to, "…interact with the world." This mother explained some of their outings as follows:

> We go to the park, or we'll go shopping, out to visit friends, or parties at friends' houses. We like the beach. Most often we'll go to the park. They have big swings and a

big slide there. Here we have the swings and slide too, but they're small, the kids are limited. It's better at the park because the kids have more freedom.

When describing her daughter's daily routine, this mother included daily errands that her daughter might accompany her on. "Maybe we'll go out to the mall, or food shopping, whatever, it depends on our plans for that day. She loves to go out, she doesn't mind, she thinks it's fun." The child, who was present during the interview, enthusiastically agreed. However, no outings took place during the day the researcher spent with this child and her family.

When the question of outings came up during the Parent-Interview with the mother of another child from the "more successful" group, she asked for her son's input. The child enthusiastically mentioned the carnival as a place he likes to go. His mother added, "We also go to the park, the zoo, the lake-he likes to go sailing, and fishing, he enjoys fishing with his Dad. He loves the swings, playing outside on the swings."   No outings took place on the day the researcher spent with this child and his family; however other people did come to the home to visit. In preparation for a visit from grandparents, this mother explained to her son that his grandparents would be visiting later in the day. She explained, "They couldn't come yesterday because Grandma wasn't feeling good and it was raining, so they're coming today to see the new house." The discussion held in preparation for a visitor may have been similar to what would take place before an outing.

Children in the "less successful" group also went on outings with their family; however, from what was observed the preparation for these events appeared limited. During the Parent-Interview, one mother mentioned that she likes to take walks with her daughter or go to the park. She said that frequently they will visit with cousins and together they will go places such as the museum or the zoo. An upcoming trip to Disney World for a cousin's birthday party was also planned. A variety of outings, in the form of local errands, occurred during the day the researcher spent with this child and her mother. These included a walk to pick up laundry and trips to local stores to buy ingredients for a recipe that the mother was preparing. No discussion occurred in preparation for these trips beyond, “Get dressed; we need to go to the store.” No discussion occurred regarding where they were going, or what they were looking for.

During the Parent-Interview, the parents of a child in the “less successful” group mentioned that, “We like going to the park, we play basketball, during the summer we like going to the lake or swimming.” They also said that their son “likes to go shopping.” During the day the researcher spent with this child and his family, one outing occurred to a park across the street from the family home. There was no discussion beyond, “Do you want to go to the park?” The boys then left with their father. The mother stayed home during this outing. Upon the boys’ arrival home however, she expressed interest in their activities asking questions such as, “Did you shoot hoops?” and, “Did you go on the slide?” An upcoming trip to the grandparents’ house was planned for the following week. This child seemed aware that this trip was coming. He stated once during the day that he did not want to wear his hearing aids, but that he would bring them to his grandmother’s house. He also mentioned that he remembered swimming in the lake at his grandmother’s house.

Although two trips outside of the home occurred during the day of observation for the third child from the “less successful” group, when the parents were asked about places they regularly went to with their child for <u>fun</u> they responded, “Here. We don’t go anywhere regularly. We’re homebodies. If we take him [child] out, we go out to eat, then that’s usually a restaurant.” While not for recreational purposes, two outings were observed during the day the researcher spent observing this child and his family. The first trip was to a local store. The child was outside playing when his father came out and announced, “I’m going to the store. You want to come?” The child agreed and climbed into the truck. His father told him that he needed to get in the back. The child did not want to and this resulted in an argument between the two in which the father physically moved his son to the back seat of the truck. At the store, the child stopped to look at a display of toys, then a display of dog food, then a display of fireworks. The father told his son, “Need cheese”. The child yelled, “NO!” An argument pursued as the father tried to pick up each item he needed. This resulted in the father picking up his son and carrying him over his shoulder kicking and screaming around the store as he picked up the needed items. When the pair arrived home, the child refused to get out of the truck. A few hours later, a trip to the veterinarian’s office for the child’s dog took place. Although this trip was discussed between the parents at various points throughout the morning, including mention of needing to give the dog a bath and the process of searching the yard for samples of dog feces to bring to the appointment, the trip was not specifically discussed with the child. Eventually when it was time to get in the car to go to the appointment, the child’s father signed to him, “Time, want, dog, doctor.” Nevertheless, the child did not appear to understand where they were going. In the car the researcher asked the child where he was going; he responded, “I don’t know, driving, that’s it,” indicating that, although the upcoming outing was mentioned at various times throughout the day, the child still did not know where he was going when he got in the car.

In summary, while outings occurred for all 6 children, parents of children in the “more successful” group appeared to be more likely to take advantage of the learning potential of the experience than were parents of children in the “less successful” group.

Daily Routines

Daily routines are included as part of the *Intentionality and Reciprocity* dimension as they contribute to the learning environment by establishing the structure that frames what happens during the day. Routines create a predictable sequence of events; this helps children to develop expectations. Routines are also grounded in values. For example, taking a bath every night communicates a value of cleanliness. Values contribute to the learning environment by establishing where and when events take place as well as how things are done and by whom.

As reported previously, in terms of quantity of occurrences in which evidence of daily routines occurred, the difference between the "more successful" and "less successful" groups was not significant at the .05 alpha level (p=.435). All six families mentioned some routine followed throughout the day. For the most part, routines mentioned by parents were observed in the home. Routines for a typical day generally included getting up in the morning, getting dressed, eating breakfast, and going off to school. Night-time routines included playtime, dinner, bath, and bedtime. No child from either group assisted in mealtime preparation and there was limited involvement with clean up.

In the home of one child in the "more successful" group, a typical day started around 5:00 am. He would get up, get dressed and drive with his mother and sister to school an hour away. After school, the child and his sister would play while their mother made dinner. At dinner time, the child and his sister would get the food they wanted from the kitchen and bring it into the dining room where the table was. According to the mother, the family usually ate together. During the day of observation, the mother ate breakfast with both of her children. The child and his mother ate lunch together as his father and sister were both sick and sleeping during lunch time. At dinner time, the mother again ate with her children. The father was outside doing yard-work during dinner time. After dinner, the normal routine was for the children to take a bath, play a bit or watch television for a short time, then bed. With the addition of a story presented in ASL on videotape before bed, this routine was followed on the day of observation.

For another child in the "more successful" group, the day started around 7:30 am. The mother explained that:

> We made the decision ourselves to drop her off at school in the morning because the bus picked her up way too early, at like around 7:00 am, then she would be so grumpy at school, so we decided it was enough of that and now we drive her to school. So, 7:30 she gets up, gets dressed, we pick out her clothes and she brushes her teeth. She doesn't eat breakfast. I've tried to force her but she just won't so we forget about that, then we drop her off at school. Then the bus drops her off here around 4:00 pm. She'll play outside… If it's a day we arrive home late, it will just be dinner then she'll go to bed, that's it.

During the week, this child's mother would pick out her clothes for her, on the weekend she did it herself. The family rarely ate together. The mother blamed this on their tiny kitchen table, however she always sat with her daughter while she ate, giving the two the opportunity to discuss her day. On the day of observation, the child and her sister ate breakfast together with their mother working nearby in the kitchen. Lunch was eaten at a birthday party attended that day. Here, the mother ate with the two girls. Given the late hour the family arrived home, no nighttime routines were observed.

The morning routine was similar in the home of another child in the "more successful" group- Getting up, discussing appropriate clothing to wear, eating breakfast, and brushing teeth. In describing dinner time the mother explained, "We eat at around 5:30. If they are really hungry maybe we'll skip snack and then eat earlier. If that happens, then they'll have a snack later, before bed…it varies." Before dinner, the children would wash their hands, after dinner, they would put their dishes in the sink. These routines were observed on the day of observation. The children ate breakfast together, lunch and dinner the whole family, including the grandparents, ate together. Nighttime routines in this household included, bath-time, putting pajamas on, brushing teeth, and getting ready for bed. Bedtime was at 8:00 pm. With the addition of looking through books, this routine was observed on the day the researcher spent with the family.

There appeared to be less of a focus on the educational value of routines in the homes of the children in the "less successful" group. The mother of one child in the "less successful" group would, "Dress her" as she was sleeping, she would, "Take her to the bathroom", then, "Give her breakfast". At night, this child would watch television as her mother made dinner. The mother explained:

> I'm trying to get her to sit at the table now, because she has this habit, and I know it's my fault, she jumps around when she's eating. I'm trying to stop that now. I don't want her to choke. But that's what I do with her.

According to the mother, after dinner her daughter would take a bath, put her pajamas on, sometimes read a book with her mother, then go to bed between 9:00 and 9:30 pm. This mother explained that her daughter would pick out her own clothes on weekends, although this was not observed during the FDO. The mother gave her daughter clothes and helped her to put them on. Aside from breakfast, which the child ate with her mother at the table, the child and her mother ate no meals together on the day of observation. The child ate lunch in front of the television, with her mother coming into the room frequently to remind her daughter to eat, occasionally putting the food on her fork for her and bringing it to her mouth. The child fell asleep watching television around 6:00pm. The mother explained that she would wake her up later to give her dinner.

The daily routine for another child in the "less successful" group began around 6:30 in the morning when he would get up and get ready for school. After school, as soon as the child arrived home, he would get on his bike and play with his friends outside. The family would eat dinner around 5:30/6:00 pm. The parents reported that their son would sometimes set the table but would not help with anything related to cleaning up. The mother explained, "They eat and then they're running off. I think that's my fault because I want to do it all." A bath followed dinner, and then "quiet-time" during which the child and his brother would watch television in their bedroom before going to sleep at around 9:30pm. During the day of observation, the boys ate breakfast together with their mother nearby. The mother also ate lunch and dinner with the boys. The father ate dinner in the living room while watching a game on television.

There appeared to be limited emphasis placed on routine in the home of the final child in the "less successful" group. According to his parents, night-time routines consisted of "bath and bathroom". Bedtime occurred between 8:30 and 9:30pm, but was frequently later when it stayed lighter out longer at night. As reported by his parents, depending on his mood, the child would help cook or set the table. On the day the researcher observed, no routines were observed. The child ate breakfast alone and although the family all ate lunch at the same time, they were in different rooms. The child ate in front of the television in his toy room.

In summary, although all families reported use of daily routines, parents of children in the "more successful" group appeared to establish structured educational routines for their children that mediated values of independence and temporal awareness. This was less likely to be the case for children in the "less successful" group. An additional difference occurred during mealtimes; children in the "more successful" group were more likely to share meals with other family members, including at least one parent. While families of children in the "less successful" group ate meals at the same time, they were less likely to be in the same room while eating; frequently, children in the "less successful" group were observed to be watching television as they ate.

Creating Environments for Learning

Creating environments for learning is considered as part of the *Intentionality and Reciprocity* dimension because parents establish learning environments based on what they value and what it is that they want their children to learn. As reported previously, in terms of the quantity of occurrences observed in which parents were observed to create environments for learning, the difference between the groups was significant at the .05 alpha level ($p=.041$). Parents of children in the "more successful" group were more frequently observed to create environments ($M = 16.67$, $SD = 3.51$) conducive to learning than were parents of children in the "less successful" group ($M = 8.67$; $SD = 3.06$). Qualitatively, this difference was most explicitly evident in how parents solicited their children's involvement in various activities in addition to the overall opportunities for learning that were present during the day of observation

Parents of children in the "more successful" group were more likely to solicit their child's involvement in routine and/or non-routine activities. For example, during the parent-interviews, in the families of the "more successful" children, the child was present for all or part of the interview and occasionally the parent would solicit the child's opinion in answering a question. In the families of children in the "less successful" group, the child was generally sent out of the room during the interview.

Parents of children in both groups reported a variety of activities that they enjoyed doing with their children. The mother of one child in the "more successful" group reported that she liked to involve her children in every aspect of her day that she can:

> I love doing everything with them. I just enjoy being with them. I always take them everywhere with me. I can't imagine being separated from them. I haven't been separated from [younger daughter] more than one day since she was born. [Child], we were apart for one week. It was awful, I cried. I just can't. I always bring the girls with me everywhere. Adult parties, everything, it doesn't matter, I bring them to the movies, to see friends, it doesn't matter, they go everywhere with me."

The mother of another child in the "more successful" group reported that she enjoyed, "Reading books with him. I also enjoy teaching him math things." According to this child's father, a favorite activity to engage in with his son was maintaining the matchbox car collection the pair shared. They had over 9,000 cars. The father enjoyed teaching his son how to discriminate fine differences between the cars. For example, he demonstrated to the researcher two cars that were exactly the same except that one had wheels with three spokes, while the other had five.

The mother of another child in the "more successful" group reported reading as one of her favorite activities to do with her child but admitted that just spending time with her children was enjoyable too.

The mother of one child in the "less successful" group reported, "I love to talk to her" as her favorite activity to partake in with her daughter. The father of a different child from the "less successful" group reported, "I like playing sports with him, certain drills he'll pick up on. I also like watching basketball or football. I also like watching movies with him just to see his reaction." "Play or watch movies" were also favorite activities reported by parents of the final child in the "less successful" group.

During the FDO, parents of children in both groups were observed to suggest activities for their children to do during the day. For parents of children in the "more successful" group, these suggested activities were either cognitive or interactive in nature. The mother of one child suggested to her son that he get out his map so that they could play with his cars; she also suggested that he play outside, and at one point in the day devised a game involving a Frisbee, tracking point-value based on where the Frisbee landed.

The mother of another child from the "more successful" group suggested a variety of activities for her children to engage in during the day. She suggested that her daughter get her puzzle to do in the morning. When the child experienced difficulty, her mother came over and directed her attention to specific areas on the puzzle such as, "See the pink stripe, match the stripe", or suggest a strategy, "Find the edges first, put that together, then the middle will be easier." During the afternoon, this mother suggested that the family play a color and shape memory card game together. She also had a ring of vocabulary words to work on with the children and math worksheets that she gave them to do. Later in the day, she introduced her daughter to the game of Hopscotch.

For the most part, children in the "less successful" group were left to devise their own entertainment; few suggestions for learning activities were made by parents. One mother asked her daughter if she wanted to watch a movie once, then the television was on for the rest of the day. In the home of another child from the "less successful" group, the mother suggested a writing activity at one time and an arts and crafts activity at another. During the FDO however, the child spent the majority of the day watching television or playing computer games. In the home of the third child, the mother asked her son if he wanted to help her make brownies. She also played on computer with him for approximately 10 minutes and both parents played baseball with him outside for approximately 20 minutes. For the majority of the day, however, this child chose his own activities.

In summary, while parents of children in the "more successful" and "less successful" groups both appeared to enjoy spending time with their children and made attempts at creating environments for learning; for children in the "more successful" group, learning was more likely to be incorporated into daily routines in which children's involvement was solicited. Activities were also suggested that engaged children cognitively, such as games and/or puzzles. For children in the "less successful" group, the television or computer generally played a central role in the environment established for learning.

Parent-Child-Activity

Parents were given the activity in "This is In and This is Not" from the book, Family Math for Young Children to do with their children. The educational purpose of the activity is to observe, describe, and sort into categories. The written description of the activity directs parents to collect a variety of items (i.e., toys, kitchen utensils, food products, etc.) to be used during the activity. Parents are then directed to designate a sorting space. The game takes place as parent and child take turns sorting items into the sorting space. The parent might begin, for example, by picking up a blue car and saying, "This is in (the sorting space) because it is blue." According to activity directions, all items are sorted dichotomously as either belonging to a designated category, or not.

Although given the same activity to do with their children, parents utilized the *Intentionality/Reciprocity* dimension considerably differently while implementing the activity.

In particular, differences were observed between the manner in which parents of children in the "more successful" and "less successful" groups set up the activity. Given the materials and sorting categories chosen, parents of children in the "more successful" group organized the activity in a manner that addressed higher levels of thinking than did parents of children in the "less successful" group. In accordance with the *Intentionality/Reciprocity* dimension, this section will discuss only how the learning environment was set up and organized. How the activities were carried out will be discussed under the second and third dimensions of mediation.

Possibly due to a misunderstanding of the researcher's expectations for the task, the mother of one child in the "more successful" group did not do the activity at all. Rather, she suggested her child get out a map and his cars and the pair spent the time allotted for this activity playing. For this reason, results from this child are not included here.

The other two families of children from the "more successful" group set the activity up as follows:

One child in the "more successful" group did the activity with both of her parents and her younger brother. Items used for the activity included toys (i.e., cars, stuffed animals, etc.) and soda cans. The parents took turns asking the child and her brother questions; the children worked sequentially rather than collaboratively. Rather than working on only categorizing, the parents used this activity as an opportunity to practice their children's knowledge of addition and subtraction concepts. For example, the child was told to pick two pink things, then two red cans. Then, she was asked how many items she had altogether.

For the other child from the "more successful" group, the activity was set up using a variety of toys (including cars, stuffed animals, etc.) and tools (hammer, wrench, screwdriver, etc.). The same materials were sorted and re-sorted in a variety of ways throughout the activity.

Specifically, the items were sorted by the following attributes sequentially: big, small, "funny feel", smooth, sticky, light or bright in color, dark in color, short, long, noisy, red, things you can eat, toys, heavy, and things that roll. No category was repeated throughout the activity and each category (i.e., with the exception of things that are sticky, and things that you eat) included more than one item. The parents encouraged their daughter's independence and decision making by prompting her to "think for herself" if she looked to them questioning the membership of an item in a group. If the child answered incorrectly, her parents prompted her to reconsider her choice, rather than telling her that she was wrong. Occasionally, incorrect answers were discussed between the parents before making a final decision and humor was used to keep the child on-task. For example, while the child was sorting red things, she picked up a tool that was more brown than red. The following conversation occurred:

Mother: Is that red? *(She shows the tool to her father)* I think this is more brown, what do you think? Is this red?

Father: Let me see *(He inspects the tool)* No, that's brown. Look carefully *(He hands his daughter a pair of Mr. Potato Head glasses).*

This set of parents organized the activity in a manner that appeared to be challenging, yet enjoyable for all three of them. They followed their daughter's lead and modified the activity as necessary to keep her interested. For example, the sorting question the child was asked changed each time a new sorting arrangement was organized. For the first sort, the child was asked which things were "big." Next, she was asked, "How many here are small?" This question involved more than counting; the child also had to reorganize the sort to arrive at an answer. Changing the question in this way altered the activity so as not to become overly predictable and redundant.

The mother of one child from the “less successful” group set up the activity using a variety of small dolls and figurines, mostly Disney Princesses and related toys. The sorting category they began with was “long hair” and “short hair.” Half of the total time spent on the activity was used to sort dolls with long hair and short hair. The mother would occasionally ask the same question multiple times before answering it herself. The next “sort” worked on was a version of labeling attributes. The mother began picking up individual items and asking her daughter dichotomous questions about each item: small or not small; yellow or not yellow; noisy or not noisy; etc. The child then took over the game, asking her mother similar questions: “yellow or not yellow”; “white or not white”. Eventually the child began to ask and answer the questions herself, “Gray or not gray? Gray; Green or not green? Green; Short or not short? Short”. The mother then asked her daughter to label all of the colors on a toy: black, blue, white, red and green. She then picked up a camera and asked, “Camera or not a camera; white horse or not a white horse”. At the end of the activity, the child picked up each doll with short hair saying, “Short hair, short hair,” etc. as she picked up each one.

In comparison to the families in the “more successful” group, the materials used by this mother were relatively homogenous (Disney Princess dolls). While these materials were engaging for the child, the homogeneity of the toys restricted the ways that the materials could be grouped. In addition, the level of challenge in how the activity was organized appeared to be mismatched with the child’s needs. The activity began with the mother asking questions at a cognitive level that the child did not appear to be able to answer (e.g., “Why is it in?”). The child generally responded by repeating her mother’s question. Later questions required the child to label attributes, a skill that appeared to be at a cognitive level lower than the child was capable of. The child responded to these questions by reorienting the task so that she herself would ask questions regarding the attributes of particular items (e.g., "this green or not green, green.").

The way the activity was organized by the other two families of children in the "less successful" group, also addressed low levels of thinking. For the second child, a variety of small toys including sponge letters and a toy dinosaur were used. The toys were set up around a large bowl (the sorting space). Although there was more variety in the materials used by this family, the items were still relatively homogenous as all toys were used. The first category sorted was hard things; then they sorted soft things. Then the game changed. The mother, the child and his brother began taking turns telling each other one thing to put in (e.g., "blue"). Similarly to the way the activity was done with the first child from the "less successful" group, the activity became focused on labeling attributes (yellow, blue, purple, green, orange, blue, big, little, horse, red, horse, blue square toy, big, green "e", soft red, blue, purple, blue, 4 hard, 4 soft, 2 horses, 5 soft, inside play) rather than sorting. As with the first child in the "less successful" group, the characteristics that items shared were not emphasized; rather, their individual attributes were focused on.

For the third child in the "less successful" group the activity was also arranged in a manner that focused on the individual attributes of items rather than the relationships among them. A variety of small toys and household items were set up on the kitchen table and the child was asked to find what was red. The activity lasted only 7 minutes; less than half of the time that other families spent on it.

In summary, parents of children in the "more successful" group were more likely to set up the task in a manner that put it on a higher cognitive level than parents of children in the "less successful" group. This was evident in the materials they used as well as the questions they asked.

4.3.3.2 Transcendence

The second dimension of mediation is *Transcendence*. *Transcendence* refers to the potential of a current learning experience to go beyond the immediate situation. The effective mediator provides information explaining why an event occurs or why a particular experience is necessary. Explanation is the critical element of a mediated learning experience that includes the dimension of *Transcendence*. The quantity of times that explanations were offered per instrument is reported in Table 4-41. As explained in chapter 3, an "event" corresponded to a period of interaction and/or dialogue between adults and children. Each transcript was divided into "events" before being coded for occurrences of use of mediation techniques. An "event" may have included more than one occurrence of mediation. For this reason, the total number of "events" reported in Table 4-41 is less than the total number of explanations reported in Table 4-42.

Table 4-41: Transcendence, Events of use by group

Instrument	*More successful*	*Less successful*	*Total*
PI	2	3	5
FDO	69	34	103
PCA	0	8	8
Total	71	45	116

As stated previously, at the .05 alpha level, the difference between parents of children in the "more successful" group and parents of children in the "less successful" group in terms of their use of *Transcendence* was not significant (p=.076). This dimension was also analyzed qualitatively. Four themes emerged from the data in the types of explanations that parents offered their children: Causal, Conditional/Relational, Instructive/Descriptive, and Temporal. The quantity of times that each of these themes occurred per child is reported in Table 4-42.

Table 4-42: Transcendence, Occurrences of explanations offered per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Causal	8	6	8	**22**	6	6	10	**22**
Conditional/ Relational	7	3	5	**15**	0	1	0	**1**
Instructional/ Descriptive	9	3	8	**20**	1	4	2	**7**
Temporal	19	9	7	**35**	3	6	4	**13**
Total	43	21	28	**92**	10	17	16	**43**

An independent-samples t-test was conducted to compare totals on types of explanations offered (causal; conditional/relational; instructional/descriptive; temporal) by parents of children in the "more successful" and "less successful" groups. At the .05 alpha level, there was no significant difference between the groups on three out of four of the types of explanations (causal: p=1.00; instructional/descriptive: p=.103; temporal: p=.127). The one exception was explanations that were categorized as conditional/relational (p=.018). Parents of children in the "more successful" group offered used conditional/relational explanations significantly more frequently (*M* = 5.00, *SD* = 2.00) than did parents of children in the "less successful" group (*M* = .33, *SD* = .577).

Given the small sample size (n=6), these statistical findings must be accepted with caution. For this reason, data were further analyzed qualitatively. Parents' use of the Transcendence dimension of mediation is further reported below in terms of how they used each of the 4 themes related to explanations (causal, conditional/relational, instructional/relational, temporal).

Explanations: Causal

Causal explanations answer the question "why" by providing reasons for an occurrence or a particular answer. Causal explanations were used at approximately equal frequency by parents of children in the "more successful" and "less successful" groups, however the quality of the explanations differed considerably.

Parents of children in the "more successful" group tended to provide more detail when offering a causal explanation. For example, when one mother explained to her son why his father and sister were sick she said, "Dad worked long hours outside last night and he didn't wear his coat. Your sister was the same. She played outside yesterday and didn't wear her coat. Now they're both sick," thereby implying a cause for the father and sister's illness.

The mother of another child in the "more successful" group used a causal explanation to answer a question asked by her daughter while they were driving. The child noticed that her mother was driving slower than usual and she asked why. The mother explained, "I'm going slow because I have to wait for [friend] to catch up." The friend was following the car to get to the next destination.

In the home of another child from the "more successful" group, the mother used a causal explanation to lessen her daughter's angst regarding the puzzle she had been working on for awhile. The child and her younger brother had both started working on different puzzles at the same time. The child appeared disturbed when her brother finished his first and said to her mother, "He's faster." The mother explained that her brother finished first because, "His puzzle is different. The pieces are bigger, there are less of them. It's easier."

Causal explanations were also used by adults in the homes of children in the "less successful" group. For example, while looking through a catalog of party-related equipment, a child pointed to a popcorn machine, saying "popcorn" and implying that she wanted this machine at her upcoming birthday party. The mother explained, "No popcorn machine. Someone could choke on it. We will have slushies, the slushies are better, and hotdogs." Often, however, explanations tended to be much less detailed. For example, during a trip to a store the same child showed her mother a butterfly sticker in a machine that she wanted. Her mother said, "No, that's a dollar." While the mother provided more of an explanation than simply saying, "No," she did not explain that a dollar was too much to pay for the sticker.

A similar situation was observed for another child in the "less successful" group. Although infrequent, at times the causal explanations offered by his parents sufficiently detailed the relationship between two events. For example, when the child requested that his mother help him with a computer game, she told him to wait because she had to feed the baby. No other examples using causal relations came up during the FDO. During the PCA, however, surface-level causal explanations were used. For example, when the mother asked her sons to find something "soft" the child responded by picking something up that did not fit the category. The mother explained, "No, that's hard." Although brief and lacking detail, this explanation informed the child of why his choice was incorrect.

For the third child from the "less successful" group, use of a causal explanation came up while he was cooking with his mother. The child looked at a dish coated with shortening and told his mother that it was dirty and that she should go wash it. The mother replied, "No, it will cook." While this explanation was not very detailed, it explained why she did not need to wash the dish. Another episode of causal explanation occurred when the child was wrestling roughly with his dog. His mother said, “Stop! You’re hurting her.” While this explanation told the child why he should stop playing roughly with the dog, only “stop” was signed, and the child was not wearing his cochlear implant at the time, so it is not known how much of the explanation was really understood by him.

Explanations: Conditional/ Relational

Conditional explanations describe the relationship between two events, one event being dependent on the other. Conditional explanations were used primarily by parents of children in the “more successful” group. A conditional explanation was only used once by a parent of a child in the “less successful” group and in this instance, it was directed at a sibling.

Parents of children in the “more successful” group used conditional explanations during the FDO to explain the relationships between events to their children. One mother used a conditional explanation to answer her son’s questions while they were playing with cars on a map. As the mother picked up a tow truck, her son asked what it was for. The mother explained, “It’s a tow truck. If a car breaks down then you need the tow truck to pick it up.” This mother did more than give the truck a label; she explained its purpose by relaying two events and the dependent relationship between them.

Another mother used a conditional explanation at a birthday party when she told her daughter, “If you don’t eat, then you can’t have dessert later. There will be cupcakes.” Using this statement, the mother explained the relationship between two events, one that was occurring now, and one that would occur at some point in the future.

The mother of the third child from the “more successful” group also used a conditional statement when she told her son to put a tray table away, “If you’re not using your table, then put it away. It’s right at [2-year-old sister’s] eye level. She can walk right into it and hurt her head.”

Only one conditional explanation was used by a family in the "less successful" group. When trying to get her youngest son to take a nap his mother told him, "You'll be wired this evening if you don't sleep." Although her deaf son was in the room while this was said, he was not watching so it is questionable whether the statement was understood by him.

Relational explanations provided information on or drew attention to the relationship between two entities. Relational explanations were used with the least frequency and were used only by parents of children in the "more successful" group.

One use of a relational explanation occurred while a child from the "more successful" group was playing with his mother. They were playing with cars on a large floor map. The mother drove her car and stopped it at a police station. She described her actions "aloud" as follows:

Mother: Okay, stop at police station, chat with my husband.

Child: No, Dad.

Mother: Dad for kids, my husband.

Doing this gave the child an opportunity to learn the differing perspectives between him and his mother regarding the man that lived in the house with them. Their relationship label differed depending on their perspective.

The mother of another child from the "more successful" group encouraged her daughter to notice relationships during a family vacation. During the Parent-Interview, the mother explained a particular trip as follows:

> Recently when we went to Indiana we decided to stop at that place, you know where flight 93 went down? In Pennsylvania? I explained to [daughter] what happened, that

the plane went down because of some bad people, then she could make that connection. She had seen the pictures, but now she could make that connection and know where it happened.

In developing her daughter's understanding of a past event, this mother directed her daughter's attention to the relationship between the pictures she had previously seen, and the location where the event took place.

During the Parent-Interview, the mother of another child from the "more successful" group explained how she helped her daughter notice relationships. She explained how she helped her daughter figure out appropriate clothing for the day as follows, "…if it's cold out, then we'll talk about, you know, it's cold you have to choose something warm to wear. We'll talk about what's better-short sleeves or long sleeves. We'll talk about what is appropriate for the weather."

Explanations: Descriptive/ Instructional

Descriptive explanations were used to explain an event or process and usually occurred in response to a child's request for information. Descriptive explanations were used more than twice as frequently by parents of children in the "more successful" group as by parents of children in the "less successful" group.

The father of one child from the "more successful" group used a descriptive explanation when he responded to a question asked by his young daughter. The children and their father were all outside. The child and his sister were playing on their bikes and the father was doing electrical work (i.e., changing lightbulbs in lights on the lawn). The sister paused from her play to inquire about her father's activities. The father explained, "I'm changing the bulbs so that when it is dark the lights will come on."

The mother of another child from the "more successful" group used a descriptive explanation to respond to her daughter's question while shopping in Target. While looking at the baby swings in the store, the child asked her mother why there were so many. The mother explained, "They swing different ways, some go side to side, others go front to back." She then demonstrated the movement with the swing.

The mother of the third child from the "more successful" group used a descriptive explanation when her son came over to investigate how many pieces his older sister had already put together on the puzzle she was doing. He counted 24. The mother explained, "There's still many more (points to number of pieces on puzzle box) 150. All puzzles are different. They have a different number of pieces. Your puzzles upstairs are different."

Parents of children in the "less successful" group also used descriptive explanations, but they were shorter and less frequent. One mother used a descriptive explanation while she was walking to the store with her daughter. The child motioned to push her mother's shopping cart. The mother responded, "[Child], be careful, it's broken. The cart is on its last legs." Another mother used a descriptive explanation when she was trying to get her son ready to take a bath she told him, "Look at your hand, it's dirty." The mother of the third child from the "less successful" group used a descriptive explanation while the family was at the veterinarian's office. As the veterinarian was examining the dog the mother explained to her son that the doctor was, "Looking for bugs."

Instructional explanations occurred with the intention of teaching something, or telling how to do something. Instructional explanations were low in frequency and were used primarily by parents of children in the "more successful" group.

The mother of one child from the “more successful” group used an instructional explanation while they were folding laundry. She explained to him how to fold a towel, “Fold once, twice, don’t roll it.” The mother of another child used an instructional explanation while working with her daughter on vocabulary words. They came upon the word “look.” The child read it and signed it “aloud.” The mother explained that there were many different ways that “look” could be signed depending on the context, and demonstrated them.

One example of an instructional explanation was coded for a child in the “less successful” group. This was used with a sibling. The father used an instructional explanation to teach his youngest son how to use a swing: “Move your legs like [child] is doing.”

Explanations: Temporal

Temporal explanations were further divided into 3 subcategories: concrete time explanations included direct references to measurable time; sequential explanations placed events in order explaining when events occurred in relation to the present time; and ‘change over time’ explanations which referred to change as a process.

Parents of children in the “more successful” group used explanations making reference to time approximately three times as frequently as parents of children in the “less successful” group. The manner in which references to time were used by parents of children in the “more successful” and “less successful” groups differed.

During the Parent-Interview, when asked if her son understood time and how she knew this, one mother of a child in the “more successful” group expressed the following:

> Yeah, I think he does, maybe more in school than here because there’s a little bit of a change. At school they eat lunch at a different time than here. Lunch is around 11 am at school but 12 pm here so he may get a bit confused. He knows the difference between

days he goes to school and days that he’s home. He gets really excited on Fridays. He’ll say, ‘There’s no school tomorrow! Yay!’

Explanations using language referring to time were used frequently in the environments of children in the “more successful” group. A concrete explanation of time was used with one child during the FDO when his mother explained, “You have to get to bed at 9:00 tonight. Tomorrow is school. You can have quiet time later, maybe put in a DVD. Tomorrow morning you need to get up at 4:30.” Language was also used frequently in this child’s presence to place events in time sequentially. For example, after coming indoors, the child informed his mother that he left his shoes outside because they were dirty. The mother responded, “That’s fine, we’ll clean them later.” They also talked about events other than the present including, a trip on a train that occurred during a previous birthday, a past event; and an upcoming birthday party and where it would be held, a future event.

During the Parent-Interview, the mother of another child from the “more successful” group reported her daughter’s developing understanding of time as follows:

> She’s looking at the clock more now. She’s starting to notice like bedtime. When it’s 8:30 she may argue with me and tell me its 7:30 and I’ll tell her ‘no, look again, it’s 8:30.’ I’m not sure if she knows other times, like breakfast, lunch, dinner. She knows that when you wake up it means eating time. When I sign breakfast, lunch, dinner, she knows the concept, but she doesn’t really know the times. She knows some of the days of the week, we’ll talk about it on Saturday: ‘no, you don’t go to school today, it’s Saturday. School is closed.’

Demonstrated use of explanations including time concepts occurred throughout the day the researcher spent with this child and her family. The mother used time concretely to answer her daughter's question as they were driving to a birthday party. When the child asked how far it was, her mother responded, "About a 20 minutes drive." At a different time, the same mother used an explanation including a sequential time concept to prepare her daughter for a future event as they were preparing to leave the house to go to a party, "When Dad gets home we're going to leave."

During the Parent-Interview, the mother of the third child from the "more successful" group also relayed her daughter's developing concept of time:

> She knows the hour, like she can look at the clock up there and tell me that it is 8 o'clock, or the digital one is more exact so she can tell me that it's 8:30. She kind of knows routine times of the day, around when she wakes up, mealtimes. It's hard because lunch time is different at school and here. At school they eat lunch at 11:30, here it's usually different. She definitely knows the days of the week, and dates, like the 10th or the 18th she'll know. She loves calendars, the patterns and picking out dates and what we're doing on specific dates. She loves it.

Explanations making use of language related to time were observed during the day the researcher spent observing this child with her family. Time language was used to make reference to future events and their sequential relationship to the present time. This was evident in the following exchange between the child and her mother:

Child: I want to go outside.

Mother: We'll see, maybe later. It's supposed to rain again. It might still be wet outside.

Child: No it's not, I looked, it's dry.

Mother: It might look dry but still be wet. You could go out, get mud on your shoes and track it into the house. We don't want that. We'll see later.

An explanation of change over time occurred in a conversational exchange between this child's brother and her mother. The brother commented on his 2 -year -old sister's baby sign for "train" saying, "She's doing it wrong." His mother replied, "She's learning, same as you before with spelling your name. Before you were really slow, but now you can spell it fast."

Parents' beliefs regarding their children's knowledge of time, and how this knowledge was demonstrated during the FDO was considerably less for parents of children in the low group.

One mother explained her daughter's knowledge of time as follows:

> She's learning like 12 o'clock, I have a clock in the other room. The big hand is on the 12 and like the little hand is on the 1 so it's one o'clock. She doesn't know the half time yet or anything. I don't think she knows times for critical events in the day (wake up, get home, etc.) She knows days of the week, she knows Friday, she knows Saturday, and she knows Sunday. If it's Sunday, tomorrow is Monday and the bus is coming to pick her up the next day and then Mommy has to go to work.

Only two explanations including a reference to time were observed during the day the researcher spent with this child and her mother. Both were sequential, talking about a future event in relation to the current time. The first reference to time occurred when the mother got off the phone with the child's aunt and said, "You're going to Florida with [aunt]. I'm going to miss you." The second reference to time came when the mother said to her daughter, "You need to take a bath soon."

In reference to the understanding of time of another child from the "less successful" group, parents relayed the following:

> [Child] is starting to understand time, at least to the hour, he doesn't get the thirties. I'm starting to incorporate it. This weekend he told me it was 8pm at snack time. He kind of

understands the days of the week, but if you were to ask him ‘do you go to school on Saturday?’ he wouldn’t be able to answer that.

Few explanations including language referring to time were used during the day the researcher observed this child with his family. The mother used an explanation including a sequential reference to time when her son saw an ice cream truck and requested ice cream saying, “Maybe tomorrow; if we hear it tomorrow.” Another explanation including a sequential reference to time occurred during the PCA when the mother explained, “I’m going to go first.”

During the Parent-Interview with another child from the “less successful” group, the parents described their son’s understanding of time as follows:

> He knows 5 pm Sunday afternoon it’s time to go to the barn. That’s when I go over to milk with my brother-in-law. He’ll come over and feed the calves, or they got cats and dogs over there. He’ll play with the other kids over there. Just depends what kind of mood he’s in. Mealtimes is what he knows mostly. Morning, dinnertime, he knows days of the week.

Very few explanations including references to time were used during the day the researcher spent with this child and his family. The mother used a reference to time and sequence when saying to the dog, “You’re getting a bath before we go to the vet.” Although the child was present when this was said, the statement was not directed at him, nor was it signed so it is questionable that he perceived it. Later on, as the family left to go to the veterinarian, the father said to his son, signing, “Time, want, dog, doctor.” The child did not seem to understand his father’s statement. When in the car, the researcher asked the child where they were going. He shrugged and responded “I don’t know, driving, that’s it.”

4.3.3.3 Meaning

The third dimension of mediation is *Meaning*. Effective mediators will encourage children to apply their concepts or ideas to their observations. The critical feature of this dimension is the questions adults ask to stimulate children's thinking. Data discussed in this section was obtained via the FDO and PCA instruments. As demonstrated in Table 4-43, questions were asked with approximately equal frequency by parents of children in both groups. The quality of questions asked however, were substantially different. Since "events" coded for *Meaning* actually referred to periods of interaction, "events" were likely to include more than one occurrence of mediation. For this reason, the total number of occurrences of *Meaning* referred to in Table 4-44 is different from the total number of "events" referred to in Table 4-43.

Table 4-43: Meaning, Events of use by group

Instruments	*More successful*	*Less successful*	*Total*
PI	0	0	0
FDO	9	6	15
PCA	23	23	46
Total	32	29	61

As reported in Table 4-44, the types of questions that parents asked were first analyzed in terms of cognitive demand. As Table 4-45 indicates, parents of children in the "more successful" group were more likely to ask their children questions that were cognitively demanding. In comparison, parents of children in the "less successful" group were more likely to ask their children surface-level questions that could be answered with recalled knowledge rather than logical thought.

Table 4-44: Meaning, Cognitive demand of questions asked

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
High Cognitive Demand	2	39	18	**59**	24	1	3	**28**
Low Cognitive Demand	0	18	15	**33**	60	13	7	**80**
Total	2	57	33	**92**	84	14	10	**108**

An independent-samples t-test was conducted to compare total number of high/low cognitive demand questions asked of children in the "more successful" and "less successful" groups. At the .05 alpha level, there was no significance (high cognitive demand: p=.471; low cognitive demand: p=.425).

The second way that questions were analyzed was in terms of requesting explanations. As reported in Table 4-45, questions that encouraged children to offer explanations were asked more frequently by parents of children in the "more successful" group than by parents of children in the "less successful" group.

Table 4-45: Meaning, Type of questions asked (explanation/no explanation)

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Request explanation	2	5	3	**10**	17	1	3	**21**
No Explanation	0	52	30	**82**	67	13	7	**87**
Total	2	57	33	**92**	84	14	10	**108**

An independent-samples t-test was conducted to compare total number of questions asked that did and did not require explanations for children in the "more successful" and "less successful" groups. At the .05 alpha level, the difference between the two groups was not significant (request explanation: $p=.513$; no explanation: $p=.949$).

Cognitive Demand of Questioning

Children in both the "more successful" and "less successful" groups were asked questions of varying levels of cognitive demand. Although the difference was not significant (questions with high cognitive demand, $p=.471$; questions with low cognitive demand, $p=.425$), overall the children in the "more successful" group were asked more cognitively demanding questions than children in the "less successful" group.

As reported in Table 4-43, despite the difference in duration between the two instruments (PCA: approximately 30 minutes; FDO: approximately 12 hours), children in both groups were asked more questions during the PCA than during the FDO. In terms of cognitive demand of the questions asked during the PCA, the two groups ("more successful" and "less successful") differed considerably. Children in the "more successful" group were asked to reflect upon the manner in which they sorted items during the PCA. One child was asked which items among a display were "big". She was then asked how many were "small", which had a "funny feel", and what things were "smooth". She was also asked to use her prior knowledge to answer questions. For example, while sorting a toy previously defined as "bright" into the "dark" pile, her mother said, "Before we talked about light and dark, I don't understand." Her father added to this with, "Is that light or dark?"

In contrast, children in the "less successful" group were primarily asked questions that were of limited cognitive complexity requiring little more than recall of known information. The mother of one child in the "less successful" group was observed to ask questions such as, "Why you put that in? I didn't tell you that goes in. Whatever has long hair goes in." Frequently, the questions that this mother asked her daughter required the child to do little more than choose between two possible options, "This is noisy or not noisy?"; "This yellow or not yellow?" When this mother did ask her daughter questions that had the potential for greater complexity, the cognitive demand was frequently reduced due to redundancy. For example, in the following exchange the mother is trying to encourage her daughter to say that dolls with long hair go inside the circle. She repeats the question many times, eventually including the response she is looking for:

Mother: Look, why she's inside? Why? Why is she inside?

Child: That, one.

Mother: Why? Why is she inside?

Child: Uh oh *(picks up one doll and uses it to knock down others).*

Mother: Why is she inside the circle? Why? Why?

Child: Mommy she *(incomprehensible).*

Mother: Okay, look, she gonna go in the circle right? Cause she has long hair, right?

Child: Okay.

Mother: Okay, who else?

Child: *(puts a doll in).*

Mother: Good job, now that's inside the circle, right? Why? Why?

Child: She have long hair.

While the child did eventually answer a question that, on the surface, appears to be cognitively demanding, she may have been simply regurgitating her mother's previous response.

Also during the PCA, the mother of another child in the "less successful" group asked her son basic-level questions. Parent and child took turns telling the other what item to pick asking, "What do you want?" Also during the activity, "Is this hard?" was asked in reference to an item's attribute. This question only required the child to consider two possible responses thereby restricting the cognitive demand.

The third child in the "less successful" group was asked two questions during the PCA that required a recall of known information, "Is this red?" and "Is there red in there?" in regards to entities present on the table. Again, these questions only required the child to consider two possible responses thereby restricting the cognitive demand.

While parents of children in the "more successful" group also asked their children questions that required less cognitive demand, in the episodes which were coded within the dimension of mediation coded as *Meaning*, children were asked almost twice as many cognitively demanding questions as questions with a more limited cognitive demand. In contrast, children in the "less successful" group were asked more than twice as many questions with low cognitive demand.

Questions Asked by Children

Children in both the "more successful" and "less successful" groups were observed to ask questions. As the information in Tables 4-46 indicates however, at the .05 alpha level, the difference between the groups was not significant (p=.541). Children from the "more successful" group were observed to ask almost twice as many questions as children from the "less successful" group.

Table 4-46: Questions asked by children, by group

Instrument	*More successful*	*Less successful*	*Total*
FDO	35	4	39
PCA	33	29	62
RCA	11	11	22
Total	79	44	123

The quantity of questions asked by each child is recorded in Table 4-47.

Table 4-47: Questions asked per child

	MS1	*MS2*	*MS3*	***Total***	*LS1*	*LS2*	*LS3*	***Total***
Number of questions asked	25	17	5	**47**	20	10	1	**31**

More important than the quantity of questions however, is the difference in the quality of questions that children asked. Questions asked by children in the "more successful" group were at a higher cognitive level than the questions asked by children in the "less successful" group. Typical questions asked by children in the "more successful" group included, "Are you deaf or hearing? Why?"; "What's it mean?" (in reference to a parent's fingerspelled word) and, "How far is it?" For children in the "less successful" group the majority of questions asked were for the purpose of clarification, for example, "In the circle?" (repeated parent's question during the PCA); and, "What did you say?" or to achieve a yes/no response, for example, "You like it?"

Request for Explanation

Children in both groups were asked questions during the FDO that encouraged them to think logically and create explanations. Although questions that encouraged explanations were posed with slightly more frequently than for children in the "more successful" group, at the .05 alpha level, this difference was not significant (p=.513).

One mother of a child in the "more successful" group asked her son a question that requested an explanation while the pair was working on a "which one is different" page in an activity book. The mother asked her son to compare two pictures asking, "Which one is different? Why?" Later in the day, this child was getting ready to go outside. Despite the warm May weather, he took the lining out of his boots. He then put the lining on his feet. His father pointed to his feet and asked him, "Why? Is it snowing outside?" Although the second question was asked in jest, both questions required the child to analyze the situation to come up with an adequate explanation. Although the parent allowed wait time, beyond a shrug the child did not offer an explanation in response to either question.

The father of another child in the "more successful" group asked his nephew, in his daughter's presence, a question during the FDO that required an explanation. While playing with water guns outside, the child pointed it at his uncle's face at close range. The father said to him, "No. If there was something inside and you shot the gun, what would happen?" When the young boy tried to escape the question, the daughter, who was paying rapt attention to this interchange, prompted him with, "You have to listen, this is important." The child's response indicated that she understood the value of the question being asked and was anticipating a response.

During the PCA, another child from the "more successful" group was asked a variety of questions that required her to analyze situations and offer explanations. One example of this occurred while she was sorting "bright" things, a concept that appeared to be new for her. When the child picked up a third toy to add to the "bright" pile, her mother said, "Yes, why?" The toy was white, the same as the first two. Her mother seemed to be probing her to expand her concept of "bright" to include colors other than white. The child responded to this by choosing other toys to add to the pile eventually including, with her mother's prompting, toys that were not white. The child was also asked to explain which items were noisy, and why they were noisy as well as which things were not toys, and why. All these questions required the child to analyze the entities under examination and compare them based on attributes that were similar and different.

One child in the "less successful" group was asked questions that encouraged him to offer explanations. While playing outside, the child showed his mother a broken truck. The mother said, "I see it got broke, what happened?" This question required the child to call upon his knowledge of the situation in which the toy was broken and offer an explanation. He responded by saying that the dog stepped on it. Later in the day, the child refused to get out of his father's truck when returning home from a trip to the store. His father asked him, "Why you want stay?" By intention, this question required the child to use a logical thought process, analyzing his reasons for remaining in the truck. However, although he was using signs at the time in addition to his voice, the father signed the first word "why" as the letter "Y". It is unlikely that the child understood the question; he did not offer a response. This child was also asked a question that encouraged an explanation during the PCA. The child expressed that he was mad and his mother asked him why. The child responded by telling his mother that he wanted a particular toy put under a paper, instead of where his mother wanted him to put it. Answering this question required the child to analyze his feelings about the situation, and develop an explanation.

While another parent of a child in the "less successful" group frequently asked questions that requested an explanation, this parent often did not allow sufficient wait-time for her daughter's response before continuing with her next statement or question. This was demonstrated during the PCA, as this mother frequently asked her daughter to explain why items were grouped the way they were, but often did not give her daughter time to answer, for example, “Why are they in the circle? Why? Why?”

Children in both groups were also asked questions throughout the FDO that did not require explanations. One child from the “more successful” group was asked what will happen after she graduates from kindergarten. This question required the child to respond at a basic cognitive level by demonstrating her knowledge that she would be going to first grade.

Another mother of a child in the “more successful” group asked her daughter basic level questions that required recall of learned knowledge as they drove to the grandparents’ house (a 40 minute drive), “Where do they live? Do you remember the town?” These questions became a bit more cognitively complex as the child was asked to detail the route after they exited the highway, “How do we go?” and “When we get to the stop sign, what do we do?”

Children in the “less successful” group were also asked questions that did not require an explanation during the FDO. While at the playground, one child was asked if he hit his brother. The child responded to the question by pointing to his shoe. The father interpreted this as, “It was an accident,” a response he relayed to his younger son. Also while in the playground, when the father turned around and saw his deaf son holding an empty soda can and a water bottle that he found on the playground, he asked him, “Did you just drink that?” The child did not respond to the question. The younger, hearing, brother of the deaf child was asked a more cognitively complex question as they left the playground. As they approached the street, the father asked him, “What do we do when we cross the street?” The child responded, “Look.” The deaf child was not present during this exchange as he had already ridden his bike out of the playground.

Another child from the "less successful" group was asked a question that did not require an explanation during the FDO. In the veterinarian's office the child's mother asked him how many dogs were displayed on a border.

In summary, while parents of children in the "more successful" and "less successful" groups all asked questions that required children to offer explanations, this type of question was not asked frequently by parents of children in either group.

4.3.4 Section Summary

As was described in this section, parents of children in the "more successful" and "less successful" groups both used the three dimensions of mediation (i.e., *Intentionality/Reciprocity*, *Transcendence*, and *Meaning*) to encourage the learning of their young deaf children. However, findings indicate that learning environments that are more conducive to learning were established in the homes of children from the "more successful" group. The home/learning environments of children from this group were language-rich. Parents in these environments, appeared to value their children's involvement in maintaining the home, were responsive to their children's wants and needs, and viewed learning as a natural process. High-quality explanations encouraging children to notice relationships between events, and consider why things happen were frequently offered. Children were also asked questions that encouraged them to consider why things happened.

Environments established by the parents of children in the "less successful" group appeared to be less conducive to learning by young deaf children. Surrounded by spoken English, these children had limited access to the daily communication happening around them. Learning in the home environment was viewed by parents as more challenging and focused on managing behavior rather than developing children's cognitive process. Explanations were seldom offered and children were rarely asked questions that encouraged them to notice relationships in the world around them, or to consider why things happen.

4.4 CHAPTER SUMMARY

As findings presented in this chapter indicate, the following characteristics were found to be associated with higher levels of mathematics achievement: deaf children whose hearing loss was discovered at a younger age, performed significantly better than deaf children for whom hearing loss was discovered later; deaf children with at least one deaf parent, performed significantly better than deaf children with hearing parents; and finally, deaf children with fluent exposure to sign language in the home, performed significantly better than deaf children who did not have fluent exposure to sign language.

Children with higher levels of mathematics achievement were also found to have a better understanding of basic concepts than their "less successful" peers. This understanding was evident in scores from the BBCS-R as well as through data obtained through naturalistic observation.

When the environment in which early knowledge was acquired was analyzed, children with higher levels of mathematics achievement were found to come from language-rich homes in which high quality mediation techniques were used, and learning opportunities were readily available. In contrast, children with lower levels of mathematics achievement had less access to language within the home environment and less exposure to high-quality learning opportunities.

5.0 CHAPTER 5: DISCUSSION

In this chapter, overall findings from this study will be summarized. Then, through a discussion of the implications of the findings of this study, responses to the following questions that were posed in chapter 1 will be offered: when does the achievement gap start; why does it start; and what can be done to lessen its impact.

5.1 DISCUSSION OF FINDINGS

This section will discuss the major findings from this study. Specifically, this section will discuss factors that were found to be associated with “more” and “less” mathematical success, in young deaf children.

5.1.1 Factors Associated with Mathematical Achievement

This section will discuss factors associated with mathematical achievement in young deaf children, as measured by mathematical ability score on the TEMA-3. First, factors associated with higher levels of mathematics ability will be discussed. This will be followed by a discussion of factors associated with lower levels of mathematical ability. Finally, additional contributing factors not specifically examined during this study, but that nevertheless may have influenced the results will be discussed.

5.1.1.1 Factors Associated with "More Success" in Mathematics

According to findings from this study, young deaf children with higher levels of mathematical achievement, as measured by mathematical ability score on the TEMA-3, are more likely: to have at least one deaf parent; to be identified as having a hearing loss at an early age, and to experience fluent exposure to sign language in their home. They also demonstrate an understanding of basic concepts that is more fully developed than that of their less successful peers. On the BBCS-R, these children all scored in the "average" to "very advanced" range across all basic concepts measured by the test, this awareness was also demonstrated in a naturalistic environment.

In the area of *number and operations*, children who were "more successful" in the area of mathematics not only noticed numbers in their environments, they also hypothesized or questioned their meaning; they counted to quantities greater than 10; and used mathematical language to make comparisons between groups using terms such as "more" and "most."

Children who were "more successful" demonstrated awareness of concepts related to *geometry and spatial sense* by grouping like shapes together when asked and accurately labeling them by name; they also used spatial vocabulary to describe the locations of items. Children in the "more successful" group willingly engaged in activities (i.e., doing puzzles and playing matching games) that could have contributed to their understanding in these areas.

These children also demonstrated their knowledge of measurement concepts through making references to time and sequence. They discussed their plans for the day as well as past and future events. They could make references to routine activities and, to a limited extent, the times that these events took place. Children in the “more successful” group were observed interacting with measurement tools such as clocks and calendars. These children also interacted with other aspects of measurement; they used language to discuss distance, speed, size and weight.

In terms of *algebraic thinking*, children who were “more successful” recognized relationships between entities. They used these relationships explicitly to complete standardized exercises (e.g., grouping objects by shape and/or color) and implicitly to make sense of their world (e.g., when lacking a known sign to label a “ladybug” it was referred to as a “strawberry”). Children in the “more successful” group also used *problem solving* naturally to complete activities and to find solutions to problems within their daily world.

In addition, children in the “more successful” group also demonstrated a healthy sense of *personal and social awareness*; they knew how to interact with others and obtain information. They followed rules and directions. Finally, children in the “more successful” group also expressed awareness of *early literacy* concepts. They used fingerspelling, wrote words, and demonstrated interest in books and printed text.

Children in the “more successful” group also experienced greater and higher quality use of mediation techniques within their families. This may have contributed to their well-developed awareness of basic concepts. These children spent a large percentage of their day interacting with adults who assisted them in making sense of their environments. Children in the “more successful” group experienced environments that were conducive to learning. In their homes learning was considered natural; routines, rules, and responsibilities were clearly defined. These children were expected to contribute to maintaining the household, to the best of their ability, and their contributions were valued and accepted. Mediating adults in the homes of children from the “more successful” group offered explanations that transcended the current moment, and asked their children meaningful questions to expand their thinking.

5.1.1.2 Factors Associated with “Less Success” in Mathematics

Children with lower levels of mathematical achievement, as measured by mathematical ability score on the TEMA-3, are more likely: to have hearing parents; to be identified as having a hearing loss at a later age than their more successful peers, and experience less than fluent exposure to sign language in their homes. Children in the “less successful” group also demonstrate a more limited understanding of basic concepts. On the BBCS-R, these children all scored in the “average” to “very delayed” range, with “very delayed” scores occurring with the most frequency. In addition, a limited knowledge of basic concepts was demonstrated in a naturalistic environment.

In the area of *number and operations*, children in the “less successful” group labeled numbers that they saw in their environment, but they did not seek explanations for what these numbers meant. They counted, but not beyond 10 and their use of mathematical language to express quantitative relationships and compare groups appeared limited.

Children from the “less successful” group had difficulty grouping like shapes together and accurately labeling them, thereby demonstrating weak *geometry and spatial sense*. Although they demonstrated an ability to consider the properties of two shapes at a time, they were unable to identify individual properties by which to link a group together, thereby showing a limited sense of *algebraic thinking*. These children also did not use spatial language to describe locations of items other than in repetition.

In the area of *measurement*, children from the “less successful” group demonstrated a limited awareness of time: they did not use language indicating sequential placement; they made limited reference to measurement tools such as clocks; nor did they seek information regarding when events would occur. These children also made limited reference to other aspects of measurement such as distance, speed, size, and weight.

Children from the "less successful" group made limited use of *problem solving*. When presented with a problem situation, they tended to behave in ways that indicated a lack of development of *personal/social awareness skills*. Children in this group were likely to demonstrate noncompliance passively (by changing the activity or disregarding a request) or aggressively (throwing a tantrum).

While children from the "less successful" group demonstrated some interest in early literacy concepts, they were rarely observed to interact with books or printed materials, nor were they observed to make use of fingerspelling.

Children from the "less successful" group experienced limited use of high-quality mediation techniques within their families which may have contributed to their lower performance in demonstrated awareness of basic concepts. They spent a large percentage of their day alone, in environments that were not conducive to independent, direct learning. Rules were not clearly defined, responsibilities were limited, and routines appeared to be rather loose. Rather than interacting with mediating adults, children from the "less successful" group spent a great deal of time finding ways to entertain themselves, frequently by watching television or playing computer games. In terms of transcendence, adults offered short explanations that were concretely tied to the "here and now", and asked questions that were cognitively undemanding.

By their own admission, parents of children in the "less successful" group acknowledged the difficulties of raising a deaf child. In terms of their knowledge of American Sign Language, parents of children in the "less successful" group could best be described as "second language learners" although, according to parent report, none had ever been actively enrolled in a sign language class at any point up to and including the time of this study. The lack of a shared language between the hearing parents and their deaf children may have placed more stress on the parents of children in the "less successful" group meaning that they were less able to focus on creating mediated learning experiences for their children. Parents may have felt that it was easier to complete a task themselves rather than explain it to their children given the challenges involved with communication.

As was discussed in chapter 2, when successful communication in the home is limited, the predominant role of conversation with the deaf child often becomes a matter of obtaining answers to direct questions or gaining specific information (Charlson et al., 1999). This phenomenon was observed in the homes of children in the "less successful" group; adults tended to offer short explanations that were concretely tied to the "here and now", and asked questions that were cognitively undemanding. Use of this type of uni-dimensional language does not encourage the higher level thinking skills such as comprehension, comparison, or evaluation necessary for informal learning (Feuerstein, 1997) (See chapter 2 for a more detailed explanation). The ramifications of a lack of exposure to this kind of communication could be a limited ability to engage in problem solving activities. As was observed in the findings from this study, children in the "more successful" group willingly engaged in problem solving activities while children in the "less successful" group did not.

As discussed in chapter 2, research indicates that family interaction and the home environment contribute to later academic success (Jimerson et al., 1999) and that quality of parenting and the language used in parent-child interaction are related to SES (Hart & Risley, 1992) with children from underprivileged families having heard less words by the time they enter preschool than children from privileged families (Hart & Risley, 2003). While specific data was not collected regarding SES, from what was observed during Level 2 data collection, the six participating families appeared to be at a similar status, at least materialistically: all families had at least one television in the home (at least two televisions were noticed in each home of a child from the “less successful” group); two families in each group had a computer in the home; parents’ level of education was similar, but slightly higher for parents of children in the “less successful” group (at least one parent of each child in the “less successful” group had a degree beyond a high school diploma). Hence, from what was observed materialistically during this study, SES did not appear to play a role in children’s achievement.

In addition, one child in the “less successful” group came from a single-parent home. Of the six families that participated in Level 2, this was also the only child out of the six families that came from a minority culture (Hispanic). This child differed in both culture and the marital status of her parents from the other children who participated in level 2 of this study. Although there did appear to be a strong extended family network in place, the researcher recognizes the possibility that these differences may have influenced the child’s level of achievement.

5.2 CONCLUSIONS AND IMPLICATIONS

This section will discuss the major conclusions from this study and their implications. Three main conclusions will be discussed: the early onset of the achievement gap; the contribution of knowledge of basic concepts to mathematics achievement; and the possibility that language is not enough to ensure academic success. Each subsection will include an explanation of the conclusion and its theoretical and/or practical implications. A study to further examine each implication is described in the section that follows.

5.2.1 The Early Onset of the Achievement Gap

Acknowledging that hearing children did not participate in this study, one important conclusion from the findings is that, based on norm scores from the TEMA-3, the onset of the achievement gap between deaf and hearing children may occur before the children even begin formal schooling. As discussed in chapter 3, the majority of young deaf children who participated in this study did not achieve scores above "average" according to the TEMA-3 ranking system; and most participants received scores that were substantially below this level. This finding suggests that, already in preschool, young deaf children are performing no better than "average;" and the majority of young deaf children are performing at levels well below this.

This conclusion has important implications for parents and teachers of young deaf children. Deaf children may not be starting formal schooling with the same knowledge as their hearing peers; therefore, the curriculum used for instruction may also need to differ.

5.2.2 Relationship between Basic Concepts and Mathematics

While children in the "more successful" group appeared to have a well-developed understanding of basic concepts, this was not the case for children in the "less successful" group. Findings from this study indicate that many young deaf children may not be naturally acquiring the knowledge of basic concepts that later learning is built upon. This finding has important implications for parents and teachers of young deaf children. Parents and teachers may need to intentionally expose the young deaf children in their charge to basic concepts as they are not acquiring them naturally and it may not be possible to develop later mathematics skills without this foundational understanding.

As discussed in chapter 2, the existence of prelinguistic schemas prior to the development of formal mathematics knowledge has been examined in previous studies. Resnick (1992, 1989) referred to young children's early mental representations of quantity as protoquantitative schemas. This concept was later observed in 2 and 4 year old children in a study by Sarnecka and Gelman (2004); children in this study were observed to have mental representations of quantity before number words were mapped onto this knowledge.

Children in the "more successful" group demonstrated similar early mental schemas for number concepts; they used these schemas to express their awareness of quantity, size, and distance in a variety of contexts. One child was observed to use the number "100" to refer to his father's age. Another child asked how far it was to their destination each time she got in the car; during a conversation with the researcher, the same child expressed knowing that New York was "very far" away from where she lived. Another child expressed a need for "really big paper" so that he could draw the researcher's home (in a different state) and his own on the same map. Another child expressed the difference between the quantities of two groups of objects as "10 and nothing" without counting. She used "10" as a number to refer to "many." As these examples indicate, children in the "more successful" group appeared to be using early quantitative schemas to express abstract mathematical concepts such as age, time, quantity, and distance. They had a mental schema for distance that they used to refer to places they could not concretely represent. They also knew that large numbers served a purpose, expressing an older person's age for example, even if they could not count that high yet. For children in the "more successful" group, this early conceptual awareness was building a foundation for later mathematics knowledge. These early conceptual schemas did not appear to be present in children from the "less successful" group.

As discussed in chapter 2, Gelman and Gallistel (1992) explain that learning to count involves mapping a preverbal concept of quantity onto a verbal and written symbol. For children in the "less successful" group, this preverbal concept of quantity did not appear to exist yet. In fact, quantitative awareness in general did not appear to exist beyond the numbers they used for counting. For these children, counting may have been a rote process with numbers serving the purpose of memorized labels rather than as tools for expressing quantitative concepts. This has implications for the children's later ability to conceptualize large numbers beyond what they will be able to physically represent. One must be able to conceptualize large numbers in order to consider for example, the population of other countries or distance while traveling. With a weaker number sense, children in the "less successful" group had fewer tools available to them that could be used to mentally organize their mathematical experiences.

In general, children in the "less successful" group did not appear to have a well developed capacity for mental representation. A contributing factor to this difficulty could be their limited ability to use vocabulary as a tool to organize their experiences. As discussed in chapter 2 (Mervis et al., 1994) labels may help with classification and recognition of superordinate and basic level categories, both in the everyday world (Anglin, 1995; Mervis et al., 1994) and mathematically (Sophian & McCorgray, 1994). In this study, children in the "less successful" group demonstrated limited use of vocabulary. One activity during which this was demonstrated was a shape sorting task. While these children demonstrated difficulty naming the shapes used during the activity, the shapes that they were able to identify accurately included circles and stars. As described in the study by Clements et al., (1999), these shapes have a limited prototype which makes them easier to identify. While children from the "less successful" group could match shapes that were visibly identical in some way (e.g., shape, color), labeling shapes by name requires recognizing the properties that define them. For example, to recognize a triangle, one must recognize the defining properties of the three vertices and three straight connecting lines. "Rules" for classification that can be recognized visually may be the easiest to recognize. As discussed in chapter 2, this supports the findings from a study by Deak et al. (2002) which indicated that, at the lowest level, children could sort items by shape; an ability to sort by function developed later.

When presented with sorting activities, deaf children, particularly those in the "less successful" group, appeared to have difficulty identifying properties that could be used as "rules" for grouping. A lack of vocabulary to state these rules may have contributed to this difficulty. For example, it is easier to organize a group of "animals" if one understands the use of the superordinate term. Without this grouping term, each animal may exist in its own distinct group as cats have characteristics that make them different from dogs. Only the terms "pet" or "animal" link cats and dogs together; the relationship between them exists in the mind of the individual who groups them and only through use of the tool of language. Vocabulary is a powerful tool for classification and one which children in the "less successful" group appeared to lack. Even when these children were able to identify a rule by which to group items together, they were unable to regroup the same items using a different rule. For example, children were unable to recognize that a shape, (e.g., a yellow square) could be grouped in more than one way (i.e., as "yellow" and also as a "square"). As discussed in chapter 2, this lack of an ability to think multidimensionally has been found in other studies that consider the thinking patterns of deaf individuals (Ottem, 1980).

Limitations in the ability to think multidimensionally could influence one's ability to notice relationships in the surrounding world and overall thinking skills. As discussed in chapter 2, "…finding clues to relationships… (Phillips & Anderson, 1993, p. 137)" is a skill frequently needed during problem solving. An individual must be able to sort out information that is and is not critical to the problem in order to arrive at a solution. While adults may recognize relationships and make connections automatically, young children are not able to do this. Relationships must be brought to young children's attention in order to broaden the connections that they are able to make on their own. However, given the challenges posed by limited communication, this was considerably more difficult for parents of children in the "less successful" group. This could be one explanation for the weaker problem-solving skills that were observed in children from this group.

Problem solving in everyday life requires an ability to recognize relationships present in the world and to make connections between events. At first, mediating adults will assist children in recognizing these patterns and attributing meaning to them. For example, when a parent of a child in the "more successful" group asked her daughter to provide directions as they drove to her grandmother's house she was encouraging her daughter to attend to the route they took. The same child demonstrated that she had acquired an ability to find relationships on her own, possibly due to the experiences with which her parents provided her, when she encountered an insect she did not have a name for (a ladybug). This child solved her problem by equating the new insect with an entity she was familiar with (a strawberry). She recognized that both were red with black dots and used this information to give the insect a name; albeit an incorrect one.

More critically, when children in the "more successful" group encountered situations where they recognized the need for more information, they asked for it. This type of active problem solving was not observed by children in the "less successful" group. They seemed to accept events as they occurred and did not seek causes or explanations. Children in this group appeared not to recognize when they needed information, they did not ask questions but rather seemed to accept events as they occurred. For example, when getting in the car with his parents and dog, a child from the "less successful" group did not appear to know that they were on their way to the veterinarian's office. When asked where he was going, the child replied, "I don't know, just driving, that's it." For him, not knowing did not appear to be a problem. The implication of this finding is that, before young deaf children can learn problem solving skills, they may first need to learn how to recognize problems when they occur.

As demonstrated in this study, an additional contributing factor to the weak problem solving skills demonstrated by children in the "less successful" group could be difficulty with social awareness. As discussed in chapter 2, the ability to engage in a problem-solving process requires self-regulation of behavior. Children must be able to hypothesize and contemplate solutions for problems.   They also need to be able to consider the perspectives of others, listen, and be able to share information and strategies for solving problems. As findings from this study indicate, young deaf children who are "less successful" in terms of mathematical ability do not currently possess these skills. These children were observed to experience difficulties focusing their attention and were unlikely to seek information when needed. This conclusion supports the findings from a previous study discussed in chapter 2. In a study by Dobbs et al. (2006), initiative, self-control, and attachment were all related to better mathematics skills, while behavior problems, withdrawal, social problems, and attention problems were related to weaker mathematics skills.

Weak formation of basic concepts could also contribute to the difficulty with formal problem solving that young deaf children experience, as reported by Ansell and Pagliaro (2006). As discussed in chapter 2, in a study by Ansell and Pagliaro (2006) children of kindergarten age correctly solved only 2 of the 6 addition and subtraction story problems they were presented with and, in general, children who were less successful at solving story problems were younger. This lack of success with formal problem solving may have its foundation in the weak formation of basic concept knowledge related to: the understanding of non-numerical terms to reference quantity; a capacity for multidimensional thinking; and an understanding of concepts related to time. Each of these topics is discussed below.

A true understanding of quantity involves more than numbers, children must also understand the relative differences between amounts represented by the different quantitative words (e.g., some, more, part, etc.) that are used in everyday life. Children in the "more successful" group were observed to use language and non-numerical terms to express and compare quantity. One child used "ten and nothing" to compare the quantities of two groups without counting them, another child was observed to use the term "beat" to compare the quantities of two groups. Beyond use of the word "more", children in the "less successful" group did not make use of quantitative language.

Lack of comprehension and use of non-numerical vocabulary to express quantitative relationships could have implications for deaf children's informal and formal problem solving skills. Informally, this lack of understanding could be reflected in expressed difficulty sharing fairly with another individual. Formally, this lack of understanding could be demonstrated in their ability to solve mathematically-based story problems. For example, the following problem from the TEMA-3 requires an understanding of quantitative language: "Diego had some candies in his lunch bag. He ate 3 of the candies at lunchtime. This left 4 candies in his bag. How many candies did Diego have in his lunch bag before he ate lunch?" Solving this problem successfully requires understanding the concept of "some" and the relationship between this concept and the numbers in the problem.

Multidimensional thinking is also required for formal problem solving, particularly when use of representations is required. In a written story problem, one "thing" (i.e., numbers) is used to represent something else. If manipulatives are used, then the need for multidimensional thinking that must be considered increases. A token, for example, must be viewed in three ways: as a "token"; as a "tool" for solving the problem; and as a "cookie," or whatever entity it is representing from the problem. As findings from this study indicate, it may be difficult for a young deaf child to view one entity using this kind of multidimensionality, thereby making formal problem solving difficult.

Lack of comprehension of concepts related to time could also have implications for children's problem solving skills. In the real-world, time concepts are used as one plans events for a day and/or decides in what sequence events should occur. These activities were observed by children in the "more successful" group. They asked for information regarding the day's activities and willingly shared their knowledge of what and when events would occur. Solving mathematically-based story problems also requires an understanding of time. For example, the TEMA-3 includes the following story problem: "Before the marble contest, Charles had some marbles. He won 4 more in the contest. Now he has 7 marbles. How many marbles did Charles have before the marble contest?" To understand this problem one must understand the concept of change over time. The problem begins with the quantity of marbles that Charles had BEFORE the contest began, and ends with the quantity of marbles that he has NOW. If a child possesses only a concrete understanding of time, existing only in the “here and now”, it will be difficult, if not impossible for him/her to be able to understand the relationship between change over time and quantity that happens in this problem.

The conclusions reported in this section have implications for parents and teachers of deaf children. Young deaf children may not be starting school with the same informal knowledge as their hearing peers. Parents and teachers cannot assume that the young deaf children in their charge are naturally acquiring knowledge of basic concepts because this is not always the case. Since, as demonstrated in this study, children with weaker understanding of basic concepts also had weaker mathematics skills, it may be critical to ensure that young deaf children are exposed to, and learn, these foundational concepts at an early age.

5.2.3 Language is Not Enough

The depressed distribution of TEMA-3 scores for children who participated in this study occurred despite the fact that the majority of participants had deaf parents and, more critically, fluent exposure to language in the home. While findings from this study showed that deaf children with deaf parents did perform significantly “better” on the TEMA-3 than did participants with hearing parents, this “better” was not enough to place them at a rank higher than “average” according to the norm scores established by the test. An important implication of this finding is that language exposure may not be enough to guarantee mathematical success in young deaf children.

It is possible that a factor contributing to this depressing distribution of scores is the more restricted opportunities for incidental learning experienced by young deaf children. The deaf child with deaf parents who sign has the opportunity to learn incidentally through observation of the conversations occurring around him/her; providing that s/he is attending to them. In contrast, for the hearing child this attending does not have to occur explicitly. The hearing child can be playing in his/her bedroom and still overhear a conversation occurring in another room. Due to the nature of hearing loss, deaf children have less constant exposure to information. For this reason, it may take more time for them to acquire the level of informal knowledge possessed by their hearing peers; if they acquire it at all.

Another possible explanation for the depressed mathematics ability scores may be the nature of the mediation that occurred within the children's households. Although children in the "more successful" group were asked more questions than their "less successful" peers, overall the quantity of questions asked by adults in the homes of <u>all</u> the children was limited. Since children who are asked questions learn how to ask questions of others, the implication of this finding is that young deaf children, particularly those in the "less successful" group, are not learning how to use questioning to obtain information they need from the world.

When presented with an educational activity to do with their child, however, the amount of questions asked by all parents increased. The implication of this finding is that parents of young deaf children could likely benefit from participation in education programs that show them how to use questioning and everyday learning opportunities to enhance their children's thinking.

In addition, the cognitive quality of the questions adults ask of children needs to be considered. Overall, the cognitive challenge of questions asked by families of children from the "more successful" group was higher than in families of children from the "less successful" group. Children in the "more successful" group were more likely to be asked questions that required them to think at a higher level by pondering *why* or *how* things happened. An interesting observation was that when adults asked children, particularly those in the "less successful" group, cognitively challenging questions that the children did not quickly respond to, the adult tended to immediately ask a new question that was less cognitively demanding. For example, during the sorting activities children were asked to put items into groups and/or to consider the relationship among items that were already grouped. If a child was unable to do this, the adult tended to pick up an item and ask, "What is this?" or revert to dichotomous questioning, for example, "Is this [toy] blue or not blue?" Changing the questions asked in this manner substantially reduces the cognitive challenge of the task. Instead of being engaged in a cognitively demanding activity that required use of classification skills, children were simply required to regurgitate memorized labels. While, to a limited extent, this tactic is appropriate to keep young children engaged in tasks, adults must remember the necessity of continuously increasing the cognitive demand of activities to which young children are exposed so that much needed thinking skills are learned.

Overall, an important implication of the findings from this study is that although fluent language exposure is a crucial component of learning, it may not be enough to guarantee mathematical success in young deaf children; rather, what is done with language may be more important. Use of high quality mediation, including frequently asking cognitively challenging questions that encourage children to think, may be a critical factor in increasing the mathematical achievement levels of young deaf children.

5.3 FUTURE RESEARCH

As implications of findings from this study indicate, there are a variety of areas in which future research is needed. Future research needs discussed in this section are divided into three categories: parent education; the role of parents and teachers; and young deaf children's understanding of mathematics.

Regarding parent education, future research studies are needed to examine the quantity and quality of parent education programs offered by schools and programs that serve deaf students. As findings from this study indicate, deaf students are currently beginning formal schooling performing already at levels no higher than "average" according to scores on the TEMA-3. Teachers alone cannot provide young deaf children with all the knowledge and skills they will need to be academically successful. Programs are needed to instruct parents and care-givers on ways to bring educational opportunities into the home environment.

In terms of mediation techniques, research is needed to examine the quality of mediation techniques used by deaf parents of young deaf children in comparison to the mediation techniques used by hearing parents of young hearing children. In both environments, young children should be acquiring and developing language normally. Research in this area is needed in order to determine if the quality of mediation techniques used by parents, regardless of hearing status, is associated with mathematical ability.

In terms of the role of parents and teachers, research is also needed to examine the effectiveness of mediation techniques used in classrooms with young deaf children. The mediation techniques (i.e., intentionality/reciprocity, transcendence, and meaning) examined in this study as used in the homes of deaf children are also applicable to the classroom. Findings from this study indicate that, for many young deaf children mediation may not be occurring effectively in the home environment; this makes the school environment more critical. In addition, research is needed to examine the correspondence between what parents and teachers believe that the young deaf children/students in their charge know regarding basic concepts, in particular, those related to mathematics, and what those children actually know. It is possible that the adults who interact with young deaf children make assumptions regarding concepts that these children know, based on their beliefs regarding concepts that children are expected to have acquired naturally by the ages of 4 or 5 years. Therefore, it is possible that young deaf children are not being explicitly exposed to the foundational concepts that they need to learn, yet have not incidentally acquired.

In terms of the young deaf children themselves, research is needed to examine the free-play behaviors of young deaf children, similar to the study by Ginsburg et al. with hearing children (1999) discussed in Chapter 2. The behaviors demonstrated by young children during a free-play situation may be indicative of their level of cognitive functioning. Children's awareness of basic concepts therefore, particularly their use of skills related to mathematics concepts, may be revealed in their play behavior. In the present study, children were primarily observed within the home environment; however, it is possible that young deaf children possess awareness of mathematics concepts that would be demonstrated through their interaction with the materials available in a classroom environment that were not demonstrated in the home environment.

An additional area where future research is needed is in examining the performance of young deaf children with "more successful" and "less successful" mathematical ability longitudinally in order to discover what impact formal schooling has on each child's developing mathematical competence.

5.4 LIMITATIONS

The researcher recognizes the existence of limitations of this study. First, this study examined a small sample. This limits the study due to the high variability (i.e., degree of hearing loss, individual differences, variation in school communication philosophy, variations in family and cultural backgrounds, etc.) both within this sample and within the population. Due to the nature of the population, this cannot be avoided.

Second, the study makes use of objective tests that have not been normed on a deaf population (e.g., TEMA-3, BBCS-R). This factor limits the study because it is possible that norms for deaf children would not match those for hearing children due to language and experiential differences. This limitation was reduced through the use of multiple means of data collection (i.e., interview, observation, etc.) and a variety of types of data (e.g., quantitative and qualitative). In addition, the BBCS-R has been used in a previous study to examine the basic conceptual understanding of young deaf children (Bracken & Cato, 1986); the researcher also informally piloted the use of the TEMA-3 with one deaf child before selecting it for use.

Third, although the design of this study includes the observation of "typical" interaction between a child and his/her family, it is recognized that simply being observed, particularly when a video-camera is present, participants may alter their behavior and thus the "naturalness" of events being observed. This limitation was reduced first, by the researcher leaving the room while the PCA was being recorded; second, by the use of field-notes rather than a video camera on the day of full-day observation; and third, through the use of "member checks" whereby families of participating children were sent transcripts and asked to review them to ensure that their perspectives were accurately recorded. In addition, family interaction was only observed for one day. It is difficult to determine what qualifies as "typical" interaction when so little time is observed. This limitation was also accounted for through use of triangulation and "member checks."

An additional limitation to the study is that the researcher did not test for language skill/proficiency in the children involved in the study. While there are several language assessment tools that could have been used to test for language proficiency (e.g., the *Language Proficiency Profile* (Bebko & McKinnon, 1998), *Kendall Conversational Proficiency Levels* (French, 1999), etc.) these were not used as they require extensive familiarity with the child's language use over time in order to accurately assess language proficiency. The researcher did not have this long-term familiarity with each child. While a possible option would have been to solicit individuals familiar with each child's language use (e.g., each child's teacher or a parent) to assess individual proficiency, this would have influenced the standardization of the assessment. While the researcher acknowledges the benefits of assessing for language proficiency in a study of this nature, this assessment was not feasible using tools that are currently available.

The researcher as an instrument was a final limitation of this study. This was a limitation as information was captured through the perspective of only one individual who brought her own biases to the task of observation. This limitation was reduced through the use of triangulation and member checks. Data were collected using a variety of instruments. In addition, transcripts were shared with families to ensure that information recorded accurately captured their perspective of the events that transpired during the day of observation, and that parents were comfortable with information recorded.

Not withstanding the limitations of the study, the data showed that there are factors associated with "more successful" mathematics ability, yet even these factors were not sufficient in obtaining scores that were beyond "average" according to the norms established by the TEMA-3.

5.5 CHAPTER SUMMARY

As discussed in this chapter, this study set out to do the following: examine when the achievement gap starts, why it starts, and what could be done to lessen its impact. The major implications of the findings from this study provide a starting place for answering these questions.

Findings from this study indicate that the achievement gap starts early. Even before formal schooling begins, young deaf children demonstrate levels of achievement that are no better than "average" in mathematics according to their scores on the TEMA-3. There are a variety of possible explanations for why the achievement gap begins including, for the lowest achieving young deaf children, a lack of awareness of basic concepts; and for all young deaf children, limited incidental learning opportunities and mediated learning experiences that may be less than optimal. Given these limitations, young deaf children may not be building "networks" of knowledge that can sufficiently support their knowledge of "numbers", or general mathematics, in preparation for formal schooling.

The most critical implication of the findings from this study is that to lessen the impact of the achievement gap it is important to start early. Findings from this study indicate that young deaf children may not be arriving at school with the same informal knowledge as their hearing peers; therefore, the curriculum used for their instruction may also need to differ. It may be critical to utilize a curriculum that includes an explicit emphasis on exposure to basic concepts and a focus on the development of thinking skills through use of mediated learning techniques. Most critically, parents and professionals responsible for the education of deaf children cannot wait until the first day of school to begin addressing the achievement gap; the preparation for formal education begins at home.

APPENDIX A

BACKGROUND QUESTIONNAIRE

Background questionnaire completed by all families during Level 1 data collection.

Background Questionnaire

Child's name: ________________________________

Child's gender: Male Female

Child's date of birth (Month/Day/Year): ____________________________________

Child's age at which hearing loss was identified: ______________________________

Cause of hearing loss: ____________________________________

Child's degree of hearing loss: _____________________________

Does child have a cochlear implant? Yes No

If yes, at what age did the child receive the implant?

____

Is the cochlear implant used more than 50% of the time at home? Yes No

Is the cochlear implant used more than 50% of the time at school? Yes No

Does the child use any other assistive listening device (i.e., hearing aids, etc.)?

Yes No

Is the listening device used more than 50% of the time at home? Yes No

Is the listening device used more than 50% of the time at school? Yes No

Hearing status of adults whom the child lives with: *(circle one for each person)*

Mother/Guardian: Deaf Hearing Hard-of-Hearing

Father/Guardian: Deaf Hearing Hard-of-Hearing

Aside from your deaf/hard-of-hearing child, do any other family members have a hearing loss?

Yes No

If yes, please list family members and their relationship to the child:

____
____
____
____

Primary language used in the home: ____

Are any other languages used in the home (please list)?

____
____
____
____
____

If sign language is used in your home, how old was your deaf child when you first started signing with him/her?

____
____

How would you describe the signing skills of each member of your household?

Mother/Guardian: **(Name)** ________________________

Beginner Pretty Good Good Fluent

Father/Guardian: **(Name)** ________________________

Beginner Pretty Good Good Fluent

Sibling: **(Name)** ________________________

Beginner Pretty Good Good Fluent

Sibling**: (Name)** ________________________

Beginner Pretty Good Good Fluent

Other: **(Name)** ________________________

Beginner Pretty Good Good Fluent

Do/Did you attend sign language classes? Yes No

If “yes” what is the highest level sign language class you have you taken?

____
____
____
____
____

Do you interact with the Deaf community? **Yes** **No**

If yes, please describe the nature of this interaction:

____
____
____
____

Parent Education Level:

Please circle the highest degree received by each parent/guardian:

Mother/Guardian: High School Diploma
BA Degree
MA Degree
PhD
Other: ___________________

Father/Guardian: High School Diploma
BA Degree
MA Degree
PhD
Other: ___________________

--

What is your relationship to the child? (e.g., mother) ___________________________

APPENDIX B

PARENT INTERVIEW PROTOCOL

Interview protocol followed during “Parent Interview” with parents of participants during Level 2 data collection.

Interview Protocol

Project: Networks to Numbers

Time of interview: ___________________
Date: ______________________________
Place: ______________________________
Interviewer: ________________________
Interviewee: ________________________

Brief description of project:
The purpose of this project is to describe young deaf children's learning at home and parents' role as their children's first teachers.

Questions:

1. Is there anything that your child learns at home that s/he could not possibly learn at school? If so, what?

2. How do you or other family members encourage your child's learning?

3. Does your child have a set bedtime? Are any routines associated with bedtime?

4. Do you eat at specific mealtimes? Are there any routines associated with eating?

5. What does your child like to do?

6. Tell me about places you regularly go to with your child for fun.

7. What is your favorite activity to do with your child?

8. Does your child's hearing loss influence the daily functioning of your family? If so, how?

9. Is any assistive technology used in your household? (e.g. captions on the television, TTY, etc.). Why or why not? If so, does your child use, or attend to use of this technology?

10. Does your child assist with daily chores (e.g. sorting laundry, putting away toys, putting away groceries, setting the table, etc.) around the house? If so, what is the nature of his/her involvement in these tasks?

11. Describe a typical day in your child's life.

    - Does s/he choose his/her own clothing? Why or why not?

    - Does s/he understand time? How do you know?

12. What is the most important or valuable part of your child’s day? Why?

13. What long-term goals do you have for your deaf child?

APPENDIX C

BASIC CONCEPTS CODING SCHEME

Coding scheme used to code basic concepts data collected from Level 2 data collection.

Basic Concepts Coding Scheme

Mathematics Concepts	*Definition*	*Examples: (what child does)*
Number and Operations	• Counts • Labels numbers in environment • Uses numbers to determine quantity • Makes use of one-to-one correspondence • Uses mathematical language (receptively and/or expressively) to express quantitative relationships and compare groups (e.g., more, less, all, a lot, beat, etc.) • Uses ordinal number words accurately (e.g., first, second, etc.)	• Counts items in environment (e.g., three fish) • Identifies numbers in environment (e.g., 1-3-5 on license plate) • Uses numbers to answer the question "how many?"; labels quantity of people sitting at a table, etc. • Uses one:one correspondence to match items (e.g., set the table) • "I have more cookies than you"; "I have a lot of books, "etc. • "I'll go first, you're second."
Geometry and Spatial Sense	• Labels shapes in environment • Puts shapes together to create pictures; includes puzzles • Uses language (receptively and/or expressively) to describe spatial locations (e.g., under, behind, in, out, next to, here, there, near, these, etc.)	• Recognizes/labels shapes in environment (e.g., triangle") • Uses spatial vocabulary (e.g., "my bear is under my bed.") • Follows directions using spatial vocabulary (e.g., "put the cup next to the plate.")
Measurement	• Uses language (receptively and/or expressively) to demonstrate awareness of measurement concepts: -Time/sequence -Distance	• Demonstrates awareness of purpose of measurement tools (e.g., clock, calendar,

	-Size -Amount -Speed -Weight	thermometer, etc.) by making use of tool appropriately • Makes reference to past and/or future events • Labels times of day, days of week and months of year (e.g., morning) • Uses language to talk about things that can be measured (e.g., distance, size, amount, etc.)
Algebraic Thinking	• Demonstrates understanding of relationships: -Identifies attributes (e.g., color, shape, etc.) of entities -Identifies how things are the same (e.g., matches beyond a one:one relationship -Makes comparisons -Classifies; identifies objects that belong together • Explains why/how things are organized or arranged • Recognizes and extends patterns	• Sorts objects by attributes (e.g., all the blue toys are together) • Cleans up, (i.e., puts things away) • "Blue, red, blue, red, the next candy will be blue!"
Problem Solving	• Gathers information needed to solve a problem • Uses strategies to solve a problem • Tells others how to solve a problem	• Asks questions to obtain information needed to solve a problem (e.g., "Why?" "What does that mean?") • Proposes solutions and/or strategies to solve problems (e.g., "the cup is broken, let's tape it together")

Personal/Social Awareness Concepts	*Definition*	*Examples: (what child does)*
Personal Awareness	• Awareness of self -Describes self -Communicates likes/dislikes, wants/needs, thoughts, and feelings • Demonstrates independence -Chooses activities -Self-reliant in self-care activities • Demonstrates pride in own accomplishments • Understands consequences of own behavior • Follows rules and directions independently • Puts materials away independently • Recognizes situations that are not safe and behaves accordingly	• Refers to self in conversation (e.g., "I want…; I need…") • Expresses independence "I can do it myself!" • Demonstrates ability to entertain self (e.g., finds games to play) • "Shows off" own work (e.g., "look what I did!") • "I spilled my milk on the carpet, daddy will be mad." • Takes shoes off before entering house • Comes inside when called by parent • Puts things away when finished with them • Demonstrates awareness of unsafe activities (e.g., tells younger sibling not to touch the hot water on the stove)
Social Awareness	• Interacts appropriately with others -Plays cooperatively and appropriately with others -Initiates and/or plays games -Takes turns - Shares -Engages in playful teasing • Demonstrates compassion; responds empathetically to others who appear upset or in need	• Asks other what they want to play • Sees another child crying and asks "what's wrong?" • Sees a child alone and asks him/her to join a game • Asks for help (e.g., getting a toy from a high shelf)

	• Makes requests appropriately -Seeks help when needed • Offers help and/or advice • Responsive to imperative statements • Recognize and respects feelings, rights and belongings of others • Demonstrates curiosity; seeks information • Asks opinions of others	• Helps others (e.g., helps younger sibling clean up toys) • Offers advice (e.g., "Be careful, it's slippery.") • Asks questions to gain information about people and places in environment (e.g., "What is that?") • Asks, "What do you think?"

Early Literacy Concepts	*Definition*	*Examples: (what child does)*
Aware of the purpose of letters, print and books	• Knows that symbols can represent objects, events or people • Understands that text/print has meaning -"Reads" environmental print - Identifies familiar words • Demonstrates interest in letters and written/fingerspelled words -Identifies letters and associates letter symbol with sign/spoken word • Shows interest in books and reading; handles books appropriately • Uses writing to communicate	• (While playing with dolls) "This is the mommy and the daddy" • Recognizes a McDonalds' sign • Points to word and asks "what does this say?" • Observes word fingerspelled and asks what it means • Asks how to spell a word • "Reads" letters on a page and represents them using the manual alphabet, or through speech • Asks parent to read a book with him/her. • Writes name on paper

Based on/adapted from:

Early Childhood Mathematics: Promoting Good Beginnings
A joint position statement of the National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM)
Http://www.naeyc.org/about/positions/psmath.asp

Logical Mathematics: Early Learning Standards for Pre-Kindergarten (Pennsylvania Education Standards)http://www.pde.state.pa.us/early_childhood/lib/early_childhood/Early_Learning_Standards_August_05.pdf

APPENDIX D

MEDIATION CODING SCHEME

Coding scheme used to code mediation data collected from Level 2 data collection.

Mediation Coding Scheme

Three Dimensions of Mediation	*Definition* *(What mediating adults do)*	*Examples*
Intentionality / Reciprocity Refers to the *where* and *when*, or manner in which the mediator sets up a learning experience. The mediating adult organizes the environment or learning situation in a manner to concretely maximize learning. *Critical Feature: Environment	*Intentionality:* • Adults establish an environment in which children can develop independence and self-sufficiency. • Adult acts in a way to consciously modify child's behavior. • Adult makes conscious use of materials and environmental tools to enhance child's learning and cultural understanding. • Adult engages in playful teasing and/or initiates conversations that are appealing to and engaging for young children. • Adult initiates learning activities, events and experiences that anticipate learning and are appropriate and engaging for young children. • Adult establishes schedules and routines that communicate information regarding family beliefs, rules, traditions and values. • Adult communicates expectation that child will learn cultural values, appropriate behavior, and use of social mores. *Reciprocity:* • Adult follows child's lead and/or is responsive to child's initiation of conversation topic. • Adult solicits child's involvement in a	*General Products*: calendars; books; reading material; environmental print; play materials; *Deaf Tech*: pagers, TTYs, videophones, etc. • Adult makes a point of looking at the clock to find out the time. • Adult suggests that the child get his/her blocks to play with. • Family plans for a trip to the zoo; they talk about what they might see there. • Child runs to his bedroom, adult says: "remember the rules, no running in the house." • Child is asked his/her preference between two activities. • Adult tells child "I like how you cleaned up your toys." • Child is reminded to say "please" when asking for something.

	conversation between others and/or encourages child to offer ideas, comments, suggestions and opinions. • Adult expresses interest and pride in child's activities and accomplishments.	
Transcendence Refers to *why* an event occurs and/or a learning experience is needed. The mediating adult has a long-term objective in mind; s/he provides the child with information so that meaning can go beyond, or transcend, the immediate situation (Feuerstein, 1997). *Critical Feature: Explanations Offered	*Transcendence:* • Adult offers explanations in order to place actions and/or events within a larger context and/or to establish causal relationships. • Adult makes reference to and/or establishes connections between past, present and future events for child. • Adult encourages child's developing awareness of self and others by encouraging independence, decision-making, and acceptance of responsibility.	• Before eating a meal at a restaurant adult tells child "you need to wash your hands before you eat, same as at home." • Adult tells child: "We need to go to the store because we will run out of milk soon." • Adult says to child, "remember when you didn't know how to tie your shoes? Now you can!"
Meaning Refers to *how* children apply their concepts or theories about the world to their observations (Ben-Hur, 1998). The mediating adult encourages the child to use logical thinking to compare events and consider causal relationships (Tough, 1985). The adult asks questions that lead the child to consider where, when and why	• Adult asks child to solve problems, answer questions, and/or offer explanations that require logical thinking, use of prior experiences/learning, or projection into abstract experiences (i.e., searching for meaning, recognition of causal relationships, considering the perspective of others or situations never experienced, etc.)	• While bringing home a pet goldfish adult asks, "remember what you learned about fish in school? What do you think your new goldfish would like to eat?" • While discussing what the child did at school adult says, "You made cookies at school today? Tell me how you

events occur and what the relationships between them are. The mediating adult interacts with the child in a manner that will promote the child's ability to think abstractly about past, present and future situations. *Critical Feature: Questions Asked		did that." • During a trip to the park, adult asks child, "why do you think the bird flew away? • Adult requests child's assistance in planning for a future event.

Based on/adapted from:

Ben-Hur, M. (1998). Mediation of cognitive competencies for students in need. *Phi Delta Kappan, 79*(9), 661-667.

Feuerstein, R., & Rand, Y. (1997). *Don't accept me as I am*. Ill.: Skylight.

Tough, J. (1985). *Talk Too*. London: Onyx Press.

APPENDIX E

FULL DAY OBSERVATION CHECKLIST

Used to record child's activity every 10 minutes throughout full day observation.

Full Day Observation Checklist

Used to record child's activity every 10 minutes throughout full day observation. Starting and ending times are approximate.

Time	Alone	Interacting with…	Activity
7:00 am			
7:10 am			
7:20 am			
7:30 am			
7:40 am			
7:50 am			
8:00 am			
8:10 am			
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7:40 pm			
7:50 pm			
8:00 pm			

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