UNDERSTANDING SPATIAL INTELLIGENCE THROUGH THE PROBLEM SOLVING OF YOUNG CHILDREN FROM CULTURALLY DIFFERENT BACKGROUNDS: AN ANALYSIS OF BEHAVIORS AND PRODUCTS

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In memory of my father, John Henry Waechter, who taught me in his own extraordinary way the true meaning of "keeping the faith".

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ABSTRACT

In this study the behaviors observed and the products created by Hispanic and Navajo children, ages four to five, are described. Each child participated in a performance-based assessment of problem solving designed to identify young children with gifts and talents. The assessment process entails careful observation of children's problem solving and resultant products to determine an individual's abilities and interests in each of the intelligences posited by Gardner (1983). All children were videotaped in the classroom while engaged in solving problems on the spatial activity of the assessment.

An embedded, multiple case study design (Yin, 1994) was used as the formal research strategy to address the research questions posed. Case study methods and qualitative techniques were used. Thus, a total of eight single case studies were conducted.

The primary purpose of the study was to describe in detail the behaviors that could be observed and the characteristics of the products created by young culturally diverse children on a problem solving task involving spatial abilities. A secondary purpose of the study was to determine if careful observation of the spatial problem solving behaviors exhibited by the children, combined with an evaluation of final products constructed, could clarify and extend the understanding of the spatial area of intelligence.

The researcher delineated three broad categories of observed behaviors and three broad categories of characteristics of final products. No sex-related differences were found between young female and male children. However, clear qualitative differences between young Navajo and Hispanic children were found in the spatial problem solving

behaviors and in the ways that spatial representations were characterized. Similarly qualitative differences were found in the eye patterns and solution strategies used by young children who were characterized as highly able problem solvers on the spatial task. The behaviors noted and the characteristics of products created by the children in this study allowed the researchers to further define spatial intelligence in 4 and 5 year old children across the core capacities of the spatial domain.

CHAPTER 1

INTRODUCTION

From the moment of birth a child shows interest in the immediate physical world she perceives. Human intelligence develops from one's observations while taking part in daily activities valued by the culture into which one is born. Basic to a child's intense desire to learn is problem solving and the spatial mode of thought.

Spatial or visual thinking involves the ability to form and hold in mind a two and three-dimensional picture or meaningful whole, and the active mental manipulation or rotation of that visual image spatially (McGee,1979; Smith, 1964). Pattern seeking and pattern analysis are the two most important features of every act of spatial thought (McKim, 1972). The modes of operation involve two steps. First, one perceives an undetailed pattern. Next, one analyzes the initial pattern for details according to one's level of interest.

Arnheim (1965) proposes that productive, creative thought in any area of human cognition is perceptual thinking. Everyone, he observed, constantly uses this ability to think in terms of pictures or physical images (Arnheim, 1969). Mental imagery or the use of visualization is a feature of spatial thinking that is important to intellectual growth. One need only observe a four year old joyfully immersed in building a block structure she considers aesthetically pleasing to have a clear image of the deep concentration and inventive play involved in the spatial ways of thinking.

Obviously, artists and architects show a strong tendency to think by visual imagery. Yet, spatial thinking is just as important to the disciplines of science and mathematics (McKim, 1972). West (1991) profiled original thinkers in the sciences and mathematics. In fact, Albert Einstein and Michael Faraday were predisposed to visualize non-verbal, abstract scientific concepts. McKim (1972) identified three broad components of visual imagery: (1) external imagery we perceive; (2) internal imagery we dream or imagine; and (3) the kind of imagery we create through drawing or painting. Furthermore, he asserts that the spatial thinker in every discipline "will be creative only to the extent that he is able to develop this flexibility and integration" (p.19). Others are more emphatic, arguing that the current system of education is one-sided and biased toward an academic curriculum that only promotes verbal thinking (West,1991; Edgar,1974; Smith, 1965). Edgar (1974) surmised: "Teachers seem to have selected the belief that intelligence is synonymous with verbal ability and that thinking supposedly takes place quite apart from perceptual experience" (p. 150). Thus, Edgar proposed that spatial thinking is a necessary part of the educational experience and needs to be promoted if students are to realize their individual intellectual potential.

For the past fifteen years, a new theory of human intelligence has attracted much attention in the fields of psychology and education (Kornhaber, Krechevsky, & Gardner, 1995; West, 1991). Howard Gardner contends that his theory of multiple intelligences offers a cultural perspective that provides a more empirically compelling understanding of human intelligence than do traditional theories of general intelligence (Chen & Gardner, 1997; Gardner, 1983; Gardner, 1993; Krechevsky & Gardner, 1994). Gardner (1983) delineated two prerequisites of human intelligence: (1) Intellectual competence entails a set of skills of problem solving and the potential for problem creation; and (2) Intellectual competence must be useful and valued within a cultural setting. Based on numerous research findings, Gardner (1983) defined intelligence as "the ability to solve problems, or to create products, that are valued within one or more cultural settings" (p. 10). He proposed the spatial cognitive ability as one of at least seven relatively independent, yet interrelated intelligences. In his view, the linguistic, musical, spatial, logical-mathematical, bodily-kinesthetic, interpersonal, and intrapersonal competencies, may develop at different rates. Similarly, he argues that competence in each frame (symbol system) of intelligence is inherent in varying degrees in all individuals.

What is unique about Gardner's theory of individual competence is that it is also a contextualized theory. Rather, Gardner contends that culture, language, and environment are important factors that influence the development of competence or the expression of creativity in one or more areas of the seven intelligences. Consequently, individuals may exhibit different, uneven profiles of abilities, interests, and range of competence across the intelligences. He points out, however, that most persons express high competence in no more than two areas of the intelligences.

More recently, Gardner differentiated the concepts “domain” and “field” from that of his definition of intelligence (Krechevsky & Gardner, 1994). Domain refers to a body of knowledge in an area of human accomplishment that develops, changes over time, and varies over the course of an individual's development. In his view, some domains are either well-defined and map directly on to an intelligence or are ill-defined and difficult to analyze and evaluate as an intelligence. Music and mathematics are examples of well-defined domains, whereas the visual-spatial area is one example of a domain that is not well defined. Field, on the other hand, refers to the roles, behaviors, social institutions, and standards related to a domain in a society. Krechevsky and Gardner (1994) concluded: " Thus, while the intelligences build on biopsychological potential, they can only be realized in specific tasks embedded in the domains and fields of a culture" (p. 291).

The intelligences can be observed when a preschool child is engaged in solving problems in meaningful daily activities and creating products that occur naturally within the context of the child's cultural and social milieu (Gardner, 1991). Consequently, different cultures place emphasis on different sets of the intelligences across a variety of settings and social institutions (i.e., public schools) (Krechevsky & Gardner, 1994). Gardner (1991) points out that the "natural mind" of a child in the early years of development is entrapped in the artifacts, values, and goals of culture well before receiving formal education in the schools. Consequently, competence in any domain of the multiple intelligences has developed and been determined by the child's culture by the time he or she is 6 or 7 years old. Moreover, the schools of most cultures stress the linguistic and logical intelligences, minimizing the importance of the other intelligences (Gardner, 1991).

Despite the limitations of Gardner's theory (Carroll, 1984; Gardner, 1983), it is a theory of significance because it stresses the importance of spatial thinking, the cultural dimension to problem solving, and elevates spatial intelligence to a status equal to verbal intelligence. Most importantly, however, Gardner's conception of intelligence acts as a catalyst for the development of alternative assessment practices and the creation of rich educational experiences that foster the development of an individual's or groups' range of intellectual potential (Chen & Gardner, 1997; Gardner, 1991).

Gardner and colleagues at Harvard's Project Zero collaborated on a project with Tufts University to develop a curriculum and alternative assessment project ((Chen & Gardner, 1997; Kornhaber, Krechevsky, & Gardner, 1991; Krechevsky, 1991; Krechevsky & Gardner, 1994). Project Spectrum was designed intentionally as an educational approach to specifically elicit a broad range of capabilities in young children, ages three to five, in several preschool settings (Gardner, 1991). Krechevsky & Gardner (1994) explained that they provided the children with a rich environment with a variety of engaging materials. Specifically, these materials were selected to characterize various adult vocations (e.g.., mechanic, musician, novelist, actor). Fifteen different assessment measures (e.g., structural tasks, observational checklists) were developed in the domains of mathematics, language, visual arts, science, music, movement, and social understanding to assess students' unique strengths and interests. This assessment battery was administered in the context of the child's classroom during the school year. Project Spectrum teachers were able to make informed curriculum decisions for their students based on ongoing observations of individual strengths and interests while each was engaged in meaningful school activity. Subsequently, an end of the year report was written profiling each child's distinctive intellectual profile and working styles (Gardner, 1983). Gardner and colleagues identified the development of different intelligences during the early childhood years (Chen & Gardner, 1997; Gardner, 1991). Clearly, these researchers provided evidence that it is possible to identify an individual profile of cognitive abilities in children as young as 4 years of age (Gardner, 1991). Thus, the application of multiple intelligences theory has utility for performance-based assessment practices that feature spatial abilities and thinking through the problem solving of young children, ages 2 through 7.

We can agree that spatial thinking is important to learning and has a central role in specialized work-related areas, as well as in the creative process. Research has shown that for spatial abilities aptitude is more highly correlated with success in numerous technological, vocational, and occupational areas than is verbal ability (McGee, 1979). The American Association for the Advancement of Science (1989) and the National Council of Teachers of Mathematics (1989) have underscored the importance of spatial abilities and problem solving skills as part of the national education reform agenda. Yet, research on spatial thinking and problem solving in young children is limited since the time of Piaget's classic study on spatial understanding.

In the field of the education of the gifted, a relatively new area of research that holds promise for the development of alternative identification methods and experimental enrichment programs for special populations of the gifted is a problem solving process model developed by Maker (1991). The framework of her approach is based on specific applications of Gardner's theory of the multiple intelligences. Over the past seven years, Maker (1992a) has worked closely with two Local Education Agencies (LEA's) in the state of Arizona to develop and evaluate new identification procedures and enrichment programs that are culturally and linguistically appropriate for Hispanic (i.e. Mexican-American) and American Indian (i.e. Navajo, Pascua Yaqui, and Tohono O'Odham) children in grades K - 3. Maker (1991) believes that "The key element in giftedness or high competence is the ability to solve the most complex problems in the most effective ways" (p. 5). Based on her definition of giftedness as problem solving ability and the continuum of problem types (Maker, 1992b; Schiever & Maker, 1991), Maker, Rogers, & Nielson developed performance-based identification procedures, curriculum, and teaching strategies. The Discovering Intellectual Skills and Capabilities While Observing Varied Ethnic Responses (DISCOVER) Model (Maker, 1992a) was refined and evaluated in varied settings. The purpose of Project DISCOVER was to develop a program that would nurture problem solving abilities across the multiple intelligences in learners of varied ages, with varied types of strengths.

Project DISCOVER was developed and implemented further in a large, urban school district as an alternative means to identify gifted kindergartners from minority populations (Rogers & Oppenheimer, 1991). Results of their findings suggest that the alternative identification process can be used to supplement a school district's identification procedures and increase minority participation in self-contained public school programs for the gifted. In a most recent study comparing the consistency between DISCOVER assessment reports and two independent ratings of kindergarten students in the multiple intelligences, Sarouphim (1999)found consistently similar results depicting individual student strengths and weaknesses in the spatial, logical-mathematical, and linguistic areas. Thus, she concluded that the DISCOVER assessment observers were effective in appraising these three areas of the intelligences through the specific problem solving activities.

Maker asserts that the DISCOVER performance-based assessment model (Maker, Rogers, & Nielson, 1993) has been used successfully to identify gifted and talented American Indian children attending public schools on the Navajo, Tohono O'Odham, and Hualapai reservations in Arizona. Furthermore, she and colleagues at The University of Arizona are using the DISCOVER curriculum model to develop culturally and linguistically relevant educational experiences and options for individuals from diverse cultural, linguistic, socioeconomic, and geographical backgrounds (Maker, Nielson, & Rogers, 1994). Building upon her previous work, Maker and colleagues developed, pilot tested, and implemented identification procedures that are culturally sensitive and developmentally appropriate in pre-kindergarten enrichment programs for Mexican-American and Navajo children, ages 3 through 5, who demonstrated limited proficiency in English (LEP). Maker (1992a) delineated several purposes of the DISCOVER IV research: (1) to develop the cognitive academic language skills of low-income and minority preschoolers; (2) to provide a rich curriculum, focused on problem solving in the seven intelligences within a cultural context; (3) to identify a profile of strengths and interests in problem solving abilities across the seven intelligences; (4) to use this information as the basis for an individual education plan (IEP) which included concrete suggestions and information about the relative strengths the child can build on; and (5) to identify those who are gifted or potentially gifted for a special program for gifted kindergarten students.

Young children from culturally and linguistically different backgrounds enter school with varied readiness experiences. Typically, educators assess children's pre-academic skills with emphasis on reading readiness to the exclusion of non-linguistic skills. Gardner (1993) discussed several principles to be considered in applying multiple intelligence theory to the assessment of intellectual profiles of children at early ages. These principles include the following: 1) all assessment needs to be done in the context of the child's natural setting; 2) all assessment needs to be sensitive to differences in the individual child's culture, abilities, development, and forms of expertise; and 3) all assessment materials need to be intrinsically motivating to the child. What is needed is a study of the spatial competencies of young children from special populations that exhibit individual profiles of problem solving abilities, strengths and interests, as well as a study of the identification of educationally relevant characteristics associated with members of groups while solving problems and creating products in a cultural context. The study of LEP and Bilingual preschool children who exhibit a range of competence in the spatial area of the intelligences is important, therefore, in helping to clarify and extend our understanding of spatial cognitive abilities and the spatial mode of thought in young children from diverse backgrounds. In addition, this information will be vital in developing appropriate educational programs and assessment practices for children from specific minority groups.

Significance of the Study

According to the 1990 Census, 31.8 million Americans spoke a language other than English at home (U.S. Census, 1990). This population will continue to increase, perhaps by 80% by the year 2000. Among the language minority groups in the U.S., Hispanics and Asian/Pacific Islanders are the largest of those who speak a language other than English. Over one-fourth of Hispanic elementary and secondary students in the public schools speak a language other than English (Pallas, Natriello, & McDill, 1989). The increasing cultural and linguistic diversity in the U.S. is likely to continue to have a strong impact on public school education.

Although Mexican Americans constitute one of the largest and youngest of the Hispanic groups in the U.S., Saracho and Spodek (1983) contend that the Mexican American population is not a homogenous group. Mexican Americans vary significantly in economic condition and social status. Given the emphasis on family ties and cooperation, Saracho and Hancock (1993) have suggested that Mexican American children "without being directly taught, learn by looking, touching, and by having people react to them" (p. 8).

In contrast, American Indians constitute a special ethnic group in the U.S. Tonemah (1987) points out that the term "American Indian" is an inaccurate description of the tribal people native to North America. Tribal people are small in number and therefore fall into the category "minority". Most importantly, he adds, tribal people are distinct from other minority groups because of the unique, legal relationship tribes have with the U.S. Government (i.e., signed Treaties). One hundred and seventy-seven distinct tribes are recognized by the federal government; twenty-one of which are in the State of Arizona. Each tribe has its own language, traditions, religion, and variances in traditionalism, acculturation, and education (Tonemah, 1987). Consequently, major differences in social and cultural values exist that distinguish the tribes from each other.

Children from different cultural groups may possess different patterns of cognitive abilities, learning styles, and problem solving (Gardner, 1983; Lesser, Fifer, & Clark, 1965). Because of social cultural factors (i.e., child rearing practices, family styles, socialization, behavioral patterns, among others) and their influence on the development of children, differences among diverse subgroups in the U.S. must be recognized, understood, and accepted by educators and policy makers (Gardner, 1983; Saracho & Hancock, 1983; Tonemah, 1987).

Gallagher (1988), in discussing the leadership role that the U.S. Government should take in strengthening programs for the gifted, stated that there is a need to better serve individuals with gifts and talents who are being underserved. He proposed that the culturally different gifted were one of several target groups that should receive top national priority. The testing of many minority students and American Indian students using culturally and linguistically biased standardized tests (i.e., intelligence, achievement, ability, and aptitude) has been a standard educational practice in the public schools. This practice has resulted in underestimating student performance, has lead to inappropriate decisions for individual children, and has made students ineligible for programs of the gifted (Chavers & Locke, 1989; Gallagher, 1988). In some public school districts, educators have relied on traditional tests to measure Hispanic students' nonverbal ability (Powers & Barkan, 1986). Berry (1994), however, questioned the use of standardized tests to measure the nonverbal intellectual ability of bilingual and LEP students. Concerning traditional tests of nonverbal intelligence, he stated: "The understanding of such material requires a form of literacy and acceptance that real-life objects and forms can be represented by lines on a 2-D paper surface. Both literacy and pictorial representation are cultural products that are learned in some cultures but not in others; moreover, styles of pictorial representation are known to vary greatly across cultures" (p. 319).

More empirical evidence is needed to determine the thought processes (i.e., spatial model, problem solving, environmental adaptation) that may be universal among young gifted students from Mexican American, American Indian tribes or other minority groups (Maker, 1983; Maker, 1991; Montgomery, 1989; Saracho & Hancock, 1993). Leung (1991) suggests that the concepts of absolute and specific aspects of giftedness are important to understanding the nature of giftedness in bilingual-bicultural children. Absolute aspects of giftedness are the underlying traits that are general and can be identified in all gifted individuals in spite of cultural, geographical, or socioeconomic differences. The ability to learn faster and more in shorter duration than most people is an example of a general characteristic of giftedness. Specific aspects of giftedness, on the other hand, vary in individuals because they are related to the values of a specific society or culture and evolve over time. Recall of old legends about landmarks important to the heritage of a tribal community is an example of a culturally specific aspect of giftedness.

Compelling evidence exists to substantiate the fact that the use of culturally biased standardized tests of intelligence, restricted definitions of giftedness, and biased traditional identification and program selection procedures have resulted in significant underrepresentation of minority students in special programs for the gifted and talented (Feiring, Louis, Ukeje, Lewis, & Leong, 1997; Maker, 1992b; Maker & Schiever, 1989; Nielson, 1994; Tonemah, 1987). Moreover, future demographic trends combined with current trends in the fields of bilingual education and education of gifted students indicate the need for alternative approaches to assessment that involve specific applications of Gardner's theory (Lopez, 1997; Maker, 1992a; Maker, 1992b). Alternative approaches to the identification of high competence combined with rich educational experiences are essential to the recognition, development, and nurturance of each individual child's interests and gifts or potential gifts and talents, particularly in the spatial area of the intelligences. Likewise, the validity of such new procedures and innovative programs targeted for the gifted need to be established for preschool children who are from diverse cultural and linguistic backgrounds.

How bilingual and LEP children identified as gifted by alternative methods express their talents and skills through solving problems of a spatial kind is becoming of vital importance. Recent research has focused on developing a general profile of intelligences, interests, and working styles of young children in preschool, first grade, and bilingual enrichment programs. A descriptive study or case study inquiry has not been done to date that has focused specifically on the understanding of spatial competence through the problem solving of young, minority children with gifts and talents.

This study will add to the increasing body of research ways of assisting young culturally and linguistically different children with high competence or gifts in the spatial area of the intelligences to realize their full cognitive potential. In addition, the results of the investigation, based on the analysis of individual profiles of spatial cognitive strengths, may expand Howard Gardner's theoretical propositions concerning the spatial domain of intelligence within two distinct cultural contexts. Furthermore, the study will be of value to educational administrators and practitioners interested in providing alternative identification procedures and enriched educational opportunities for preschool-age minority children to express their giftedness or potential gifts in spatial ways.

Statement of Purpose

The primary purpose of the study was to describe in depth, behaviors that could be observed and characteristics of products created by participants who engaged in open ended problem solving activity involving the spatial area of intelligence. These in-depth descriptions, combined with two other sources of information, were the basis of individual profiles of spatial competence for each of the participants. A secondary purpose of the study was to determine if careful observation of the problem solving behaviors and an evaluation of the final products could clarify, expand, and inform theory about the spatial intelligence of young children.

Research Questions

Underlying the purpose of this study are the following research questions:

1. What behaviors are observed in young children engaged in solving problems involving spatial abilities?
2. What are the characteristics of products created by young children engaged in solving problems involving spatial abilities?
3. What differences in behaviors and products are noted within and across participant groups?
4. How are these behaviors and products similar to the core capacities of spatial intelligence as theorized by Gardner (1983)?

Definition of Terms

In seeking answers to the research questions above, the following terms needed to be understood.

Bilingual: The children who have developed skills in some areas (i.e., listening, speaking, reading, writing) with varying degrees of control over English and their native language. In this study, however, bilingual refers to the children who have developed prereadiness skills in listening and speaking with varying degrees of control over English and Spanish or over English and Navajo.

Hispanic: The heterogeneous group of citizens of the United States who are of

Mexican heritage and who speak the Spanish language. In this study, however, Hispanic refers to persons of Mexican American heritage who are bilingual or have some knowledge of Spanish and reside in an urban city in Southern Arizona.

Navajo: The Diné Indians of Arizona, Utah, and Northern New Mexico, who speak the Athapascan language. In this study, however, Navajo refers to persons of the Diné clans who are bilingual or have some knowledge of the Navajo language and reside on the reservation in a rural community in Northeastern Arizona.

Spatial Intelligence: A combination of human abilities related to the spatial mode of thinking. Gardner (1983)delineated loosely related capacities of the spatial domain of intelligences that are not exclusively tied to the visual sense. These key aspects include the ability to recognize instances of the same element; the ability to transform or to recognize a transformation of one element into another; the capacity to conjure up mental imagery and then to transform that imagery; and the capacity to produce a graphic likeness of spatial information. Other terms for spatial intelligence include spatial ability, visual spatial ability, perceptual thinking, spatial thinking or visual thinking.

Spatial Ability: The cognitive ability to perceive and solve problems associated with spatial orientation and/or spatial relationships between objects or figures including position, direction, size, form, and distance. In this study, spatial abilities are behaviors that could be observed while students were engaged in solving problems encountered and/or created while completing a block construction activity with varied degrees of structure.

Young Children: Children aged birth through approximately 8 years. In this study, young children are preschool-aged children, ranging in age from 4 years, 0 months to 5 years, 3 months.

Assumptions

The researcher relies on the theoretical framework of Gardner's (1983) theory of multiple intelligences and Maker's (1992) conceptualization of problem-solving and giftedness. This study has been guided by the following tenets:

1. Children are capable of at least seven different ways of knowing the world. Every individual has strengths and interests in one or more of the domains of the intelligences.
2. Developmental progress in the spatial area of intelligence depends on the interaction of a child's individual differences or biology with differences in the learning opportunities present in the child's immediate cultural environment.
3. All children possess various degrees of cognitive abilities that are valued by a culture. These abilities can easily be observed while the child is engaged in high interest activities present in the child's home and/or classroom.
4. Problem-solving is a significant construct in the identification and development of gifts and creativity in children.
5. Blocks are one of the chief manipulative materials found in early childhood programs across the U.S.
6. Blocks are a satisfactory diagnostic medium to be used in observing the problem

solving and self-expression of children four to five years of age.

7. A child as young as four to five years of age will be able to produce block constructions, for example, that are likenesses of spatial information, either real or imagined.

Limitations

Limitations of this study include the following:

1. The researcher described the behaviors observed and the characteristics of products created by four 4-year-old to 5-year old Hispanic children and four 4-year-old to 5-year-old Navajo children from differing geographic locations. Results of this study can be generalized only to the two populations studied.
2. The data in this study were collected and analyzed by some individuals from cultural, linguistic and socioeconomic backgrounds other than those representative of the participants. Therefore, the researcher takes responsibility for any misinterpretation of data that results from lack of cultural and linguistic sensitivity.
3. Researcher and observer biases may have limited accurate descriptions and interpretations of participants' behaviors and final products.
4. All Project DISCOVER IV Research Team members, including the researcher and the research assistant, participated in the identical assessment process training. However, this participation did not insure consistency in the way the videotaped sessions were conducted.

5. Motivational factors affecting behaviors observed during the problem solving activity involving spatial intelligence were not considered in this study.
6. Most children from western cultures are familiar with blocks and have some experience in block play. Yet, they may vary in meaningfulness to children in their daily lives.

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter is an integrative review of the literature characterizing the current state of knowledge surrounding group differences in the spatial abilities and problem solving of young children. The primary purposes of the review of the literature are (1) to determine whether one can detect differences in the spatial abilities of young children, particularly those from distinct cultural heritages; and (2) to determine whether one can detect differences in the problem solving strategies of young children either with high or those with superior cognitive abilities. In addition, the theoretical framework of the study as it pertains to spatial intelligence and young children will be presented. The research reviewed in this chapter is organized around and driven by the research questions of the present inquiry.

Four criteria guided the selection of journal articles and dissertation studies from inclusion or exclusion of the research to be reviewed:

1. The chronological ages of study samples had to include children from 2 through 8 years of age.
2. Studies included meta-analysis, causal-comparative, correlational, quasi-experimental, or qualitative methods.
3. The sample had to be "identified" by a test score, and/or demographic information.
4. Studies focused solely on spatial abilities and mathematics, science, music, or

cognitive development were excluded from this review of the literature. Also excluded were studies related to test construction in the spatial area of human cognition.

Computerized searches were made of the ERIC and PsychINFO databases from 1978 through 1998 using the descriptors "spatial ability" and "young children"; "spatial ability" and "culture" or "cross-cultural studies" and young children; "problem solving" and "young children" and "gifted education". The studies were located by examining all articles listed under these terms. Additionally, these terms were used to search unpublished studies in Dissertation Abstracts International. Other studies were located by a manual search of the following journals: *Review of Educational Research, Review of Research in Education, Gifted Child Quarterly, Journal for the Education of the Gifted, and Roeper Review*. The two searches combined produced a list of 12 relevant articles. In a majority of the studies, researchers reported findings statistically, however, several studies included findings based on qualitative methods. In Table 1, the number of studies concerning each of the questions addressed in this review are listed.

Studies of Sex Differences and the Spatial Abilities of Young Children

In their thorough review of the literature on this topic, Maccoby and Jacklin (1974) concluded that reliable sex difference can be found in spatial abilities favoring adolescent males Caplan, MacPherson, & Tobin (1985), however, argue that this widely accepted conclusion is not warranted because there are serious problems related to the construct of spatial ability.

Table 1 Number of Studies According to Review Question Category

Question Category	Number of Studies
Spatial Abilities of Young Children: Sex Differences	7
Spatial Abilities of Young Children: Cultural Differences	3
Problem Solving and Young Gifted Children: Ability Differences	2

McGee (1979) in his extensive review of the literature, reached the following conclusions relative the spatial abilities and problem solving of young children: (1) sex differences are less reliable in children under 12 years of age; (2) sex differences have not been found to emerge in young children under the age of six years; (3) sex differences could be due to social as well as biological influences; and (4) spatial ability may be an important component of ability in problem solving and mathematics.

In a more recent meta-analysis of empirical studies of sex difference and spatial abilities, Linn and Petersen (1985) provided contrary evidence. They found that no significant sex difference between males and females existed on measures of spatial visualization. The researchers concluded that in the area of spatial visualization performance appears to be more dependent on the use of metastrategies than it does on sex difference. On tests of mental rotation, however, large differences continue to be detected in the performance of males by age 13. Small sex differences favoring males were found on measures of spatial perception and detected in boys as early as age 8. In support of McGee's interpretation, however, they do contend that when sex differences are found, they can be detected across the lifespan.

Etaugh and Levy (1981) investigated sex differences in young children. They assigned 4 to 5 years old children, who were right handed, into two groups (n = 23 boys and 23 girls). They found that the overall performance on a task of tactile-spatial processing did not differ significantly. Thus, sex differences between males and females were not detected in preschool-age children. These findings lend further support to the earlier findings by

McGee. In addition, they found that as early as 4 years of age both sexes showed the emergence of greater right hemisphere specialization for spatial processing.

Johnson and Mead (1987) adapted seven spatial tests developed for adults and combined them into a test battery for use with children ranging in age from 6 to 18 years old. They administered this battery to 1,800 public school children from middle and low socio-economic backgrounds. Students were divided into four groups by age and grade level. Statistical analyses of group test performance revealed a male advantage that was reliably detected by age 10 and which remained constant through age 18. Thus, their conclusions corroborated those of previous studies. That is, that no indication of sex differences was found in the performance of kindergarten children on a wide range of spatial tests.

Research into spatial mapping abilities and the social interactions of young school aged children (grades kindergarten to fourth grade) suggest some sex related differences favoring boys. Mathews (1987) developed a map construction task of a large-scale area in Coventry, England to assess the spatial competence of school age children. He relied on quantitative and qualitative methods to analyze the spatial orientation strategies and map constructions of children, 8 and 11 years old. Two groups of participants (Group A and B) were formed on the basis of similar sex and environmental experience. Participants were directed to construct a map (drawing) of the unfamiliar area they had visited. Participants in Group A were given a more complex task than were those in Group B. Research results showed that boys outperformed girls when the spatial task was more complicated on all but one of the assessments. Therefore, Mathews (1987) concluded that sex differences favoring boys do exist. According to the researcher, the superior performance of boys in map reading and construction of home area cognitive maps may be attributed to a high level of activity in the environment. Similarly, Boardman (1990), in his review of the literature, concluded that older, primary school aged boys consistently perform better than girls of the same chronological age on spatial tasks of map reading and map drawing. However, no significant differences were found in the performance of younger male and female children on map reading and map drawing tasks.

In a related study, Canella (1992) investigated the spatial learning of 5 to 7 year olds (N = 66) on spatial perspective-taking tasks requiring participants to recreate three transformations of varying complexity. Canella (1992) found a significant multivariate effect for gender and partner. Male participants paired with other males made greater developmental gains than did females paired with like partners on tasks of spatial cognitive learning. She concluded that differences between the cognitive growth displayed by males and females during social interaction may be affected by the content used in solving problems involving spatial abilities. Table 2 is a summary of the studies of sex differences and the spatial abilities of young children cited above.

Limitations of the Studies

The McGee (1979), Linn and Petersen (1985), and Johnson and Meade (1987) studies were particularly thorough and well designed. Overall the sex difference studies are valid and support previous findings indicating that differences in spatial abilities of

Table 2. Summary of Sex Differences and the Spatial Abilities of Young Children

Study	Studies/Participants	Spatial Tests/Tasks	Design Analysis	Conclusions
McGee (1970)	Studies published from 1930-1970	Spatial Visualization Tests Spatial Orientation Tests Spatial Perception Tests Map reading tasks Mental Rotation Tests	Factor Analysis	Sex difference favoring males. Sex differences on tests of spatial visualization and orientation do not appear until puberty. Males have greater right hemisphere specialization than females. Sex difference less reliable among children under age 11 years. Sex differences failed to emerge in children under the age of 6 years. Male Superior performance on spatial ability tests may be enhanced by x-linked recessive gene.
Etaugh & Levy (1981)	46 preschool children	Tactile-spatial Processing Task	ANOVA	Male and females showed greater right-hemisphere specialization for spatial processing as early as 4 years of age. No sex differences in specialization or over-all performance.
Linn & Petersen (1985)	Studies published from 1974-June 1982	Spatial Perception Tests Mental Rotation Tests Spatial Visualization Tests	Meta-analysis	No significant sex differences on measure of spatial visualization. Large sex differences only on measures of mental rotation. Small sex differences on measures of spatial perception. When sex differences are found, they can be detected across the lifespan.

Table 2. Summary of Sex Differences and the Spatial Abilities of Young Children

Study	Studies/Participants	Spatial Tests/Tasks	Design Analysis	Conclusions
Matthews (1987)	School children less complicated primed task School children more complicated primed task	Map Construction Task	Chi-square Qualitative analyses of map content	Boys performed better than girls in all but one of the spatial tasks.
Johnson & Mead (1987)	1,800 public school students	Battery of seven modified adult spatial tests (paper-and-pencil)	ANOVA	Feasible to measure spatial ability throughout this developmental range with modified version of adult tests. Sex Differences in spatial performance appears reliable by grade 4. Magnitude of sex differences remains constant through age 18. No sex difference in kindergarten children.
Boardman (1990)	Studies published from 1980 to 1990	Sketch-map construction task Map reading task	Review of literature	Past research underestimated the ability of young children to handle maps. No sex differences in mapping abilities of young children. Older boys performed better than same-age girls in map drawing and map reading
Canella (1992)	33 pairs of young children	Three Spatial Cognitive Perspective-taking Tasks	ANOVA MANOVA	Males placed with males progressed more following social interactions than mixed gender or all-female pairs.

young children are clearly not detectable in younger children.

A critical evaluation of the other studies, however, revealed deficiencies in the methodology which cast some doubt on the interpretation of the results of four of the seven studies. In particular, the Mathews (1987) study findings were clouded by several major problems related to methodology. The researcher was detailed in the description of the map construction task and assessment procedures used in his investigation, yet he failed to provide an adequate description of the population studied and the methods used to select the sample of school children. Moreover, Mathews did not establish statements of reliability and validity for the map construction instrument he developed. Likewise, he failed to report intra-rater reliability measures. Finally, the researcher concluded that the male superior performance on complex tasks of map reading and construction are likely caused by a high level of activity in the environment. However, he failed to provide statistical results to substantiate his environmental activity-related hypothesis.

The review of the literature conducted by Boardman (1990) paled in comparison to the rigor of the McGee (1979) study and the meta-analysis conducted by Linn and Petersen (1985). In addition, the researcher did not report methods of analysis. Thus, his review of the literature was an integrative, critical analysis of the empirical studies related to the map reading of young children.

Problems of small sample size were evident in the study by Canella (1992) and the one by Etaugh & Levy (1981). In the Canella (1992) study children between the ages of 5 and 7 years were selected from five classrooms in a culturally mixed urban school (N = 66, 34 males, 32 females). The participants were then randomly paired into two groups of 33 children. In the investigation by Etaugh and Levy, 46 right handed, preschool children were sampled. Subsequently, the researchers divided the sample into two equal groups of boys and girls. According to Isaac and Michael (1984), the subsample units, not the sample units, are the critical units of comparison used in estimating the sampling error. The smaller subsample size reported in each of the studies should be considered the true sample size. Thus, the results of the two research investigations are limited generalizability to the larger populations of the respective samples. Additionally, Etaugh & Levy (1981) and Canella (1992) used the sample units of comparison instead of the true, smaller subsample size to convert the quantitative findings to an effect size. If the smaller units of comparison had been used as the basis for the statistical analysis, then the effect size likely would be much lower than actually reported by the researchers in their respective studies (Thompson, 1996). Thus, the quantitative methods used in these studies show an elevated and perhaps biased effect size.

Studies of Cultural Differences and the Spatial Abilities of Young Children

According to some researchers investigating cross-cultural differences, certain cultural and linguistic groups display distinctive profiles of cognitive abilities. Researchers investigating differences in the spatial abilities of young children provided evidence of superior spatial abilities and related skills within several groups of children of different cultural heritages and linguistic backgrounds (i.e., traditional Chippewa, traditional Japanese, and second-generation Chinese American). These researchers predicted superior spatial abilities in the cultural performance patterns of the children in their studies as measured by standardized tests of young children's cognitive abilities. They concluded that traditional American Indians possess a distinctive profile of cognitive abilities that is markedly different from that found in non-minority children. As such, researchers have claimed that American Indian children as a whole have unique strengths in spatial abilities, visual memory, and observational cognitive learning styles that reflect the traditional tribal heritage (Kleinfeld & Nelson, 1988). In general, Wechsler Scale research results provide evidence of the existence of an American Indian test performance pattern, a significantly high spatial subtest score and a significantly low verbal subtest score (McShane & Plas, 1982).

A diverse pattern of intellectual abilities in Japanese children has been noted indicating strengths in spatial abilities. Despite contradictory results from one study, several researchers have reported a range of values for the mean IQ scores of Japanese children (i.e., mean = 106, 111, 113, 138) in relation to the mean IQ scores of American children (i.e., mean = 100) (Lynn & Hampton, 1986). Similarly, qualitative differences have been noted in the quality of drawing skills between young Chinese and American children (Gardner, 1989). Thus, Chinese preschool age children displayed exceptional drawing abilities.

The extensive literature search yielded only three studies. However, researchers, in each of the three investigations, reported evidence for the existence of a cultural performance pattern in the spatial area that is different from that found in young nonminority children. The first study of cultural differences in spatial abilities of children, ages 4 ½ to 16 years, was conducted by McShane and Plas (1982). Over a period of ten years the Wechsler Scales were administered to 142 American Indian Children. The majority of the sample included children of Chippewa heritage. The sample included other tribal groups, also. The researchers recategorized the participants' subtest scores from the Wechsler Scales into sets of factored abilities according to a specific scheme. The investigators of the study hypothesized the existence of a pattern of American Indian performance that differs from that found in LD groups or within the norming group of the Wechsler Scales. Significant levels for the analyses were set at .05 or better. Analyses confirmed the expected pattern of recategorized scores within the total Wechsler groups. The spatial scores were significantly higher than all others within the sample. The researchers concluded that the findings provide evidence for the existence of a cultural performance pattern that shows spatial abilities to be more developed in traditional Chippewa children than those who are acculturated or LD. Thus, the results support the findings of previous studies.

In two other studies, comparable results were found. Researchers provided evidence of the existence of distinct cultural differences with spatial abilities more well developed in preschool age children of Asian heritage. Lynn & Hampton (1986) reported differences in the spatial abilities of over 100 Japanese children. Using the McCarthy Scales of Children's abilities, Lynn & Hampton quantified values for Japanese abilities according to a specific hierarchical model of intelligence. They hypothesized that Japanese children, when compared to the American norming groups of the McCarthy Scales, would exhibit a distinctive profile of abilities with spatial performance being the highest of the scores. The Japanese children displayed a diverse pattern of abilities. They scored lower on the verbal and memory subtests of the McCarthy Scales and higher on the perceptual-performance scale than did the children in the American norming group. However, the performance scores between the two diverse groups of children did not differ by ages 7 ½ and 8 ½. Huntsinger and Others (1994) examined differences in drawing performance, creativity, and related skills in the spatial and fine motor areas between second generation Chinese American children (i.e., mean age = 5.6 years) and Caucasian American children (i.e., mean age = 5.7 years). The Chinese American children were more mature in their drawing and handwriting skills than were the Caucasian American children. In addition, the drawings of the Chinese American children were rated as more creative than those of the Caucasian children. This finding was contrary to their predictions. Thus, the researchers concluded that the higher performance among the Chinese American children shows superior skills in the spatial and fine motor areas. Table 3 is a summary of the studies of cultural differences and the spatial abilities of young children.

Limitations of the Studies

Each of the studies has limited generalizability because of problems related to methodology. Although the samples were adequately described and the procedures involved were delineated, the researchers did not use methods of random sampling; therefore, the findings are only representative of the majority of children in each of the

Table 3. Summary of Spatial Abilities, Cultural Differences, and Young Children

Study	Participants	Spatial Tests/Tasks	Design Analysis	Conclusions
Huntsinger & Others (1994)	40 Chinese American preschool/kindergarten children 40 Caucasian American preschool/kindergarten children	Tests of Early Mathematics Ability-2 The Draw-A-Person Test Visual discriminations, Spatial relations, and Name writing tasks	MANOVA Univariate Analysis	- Chinese American children were more advanced in drawing and handwriting than were Caucasian American children. - Chinese American children's drawings were rated as more creative. - Girls drawings were more mature than those of boys. - Chinese American parents set aside more time each day to focus on fine muscle activities than Caucasian American parents.
Lynn & Hampson (1986)	100 children at each of 10 age groups (2 ½ through 8 ½ range) in the U.S. standardization of the McCarthy Scales. 50 - 60 children for each of the 10 age groups in the Japanese standardization of the McCarthy Scales.	McCarthy Scales of Children's Abilities	Factor Analysis	- Japanese children do not differ from American children on general intelligence; however, they scored significantly higher on the group perceptual factor (i.e., spatial and drawing abilities) and significantly lower on the group verbal factor (i.e., verbal comprehension, memory, and word fluency).
McShane & Plas (1982)	142 American Indian Children (i.e., Chippewa, Sioux, other tribal groups) ranging in age from 4½ to 16 years.	Wechsler Scales: WISC, WISC-R, and WPPSI subtest scores	ANOVA Frequency Analysis	- This group of American Indian children is characterized by a different Wechsler Scale performance pattern than that found in LD groups or within the norming group; participants displayed high visual spatial skills, moderate sequential skills, low verbal-conceptual skills, and acquired factual knowledge.

study samples investigated.

The problem of small subsample size clouded the results of the McShane and Plas (1982) study and the Huntsinger and Others (1994) study, as well. The researchers subdivided the original samples reported. In the study by McShane & Plas, the sample (N = 142) was evenly distributed on the variable of sex. However, the researchers divided the sample into three groups based on the Wechsler Scales (i.e., WISC, n = 78; WISC-R, n = 52; WPPSI, n = 12). The WISC and WISC-R subsamples were divided further into four more groupings, the Traditional Indian group (WISC, n = 48; WISC-R, n = 29) and the Acculturated Indian Group (WISC, n = 29; WISC-R, n = 23), respectively. In the study by Huntsinger and others, the researchers included 40 preschool and Kindergarten children. They divided the sample into two groups equally divided by the sex variable and grade level.

Studies of Problem Solving and Young Gifted Children

Problem solving is a widely valued cognitive ability usually included in current definitions of giftedness and creativity. Maker (1993) asserts that creativity and giftedness are within the same construct. According to her definition, gifted individuals are competent problem solvers who are capable of solving a range of problem types, from well defined to ill-defined, in the most efficient, effective, and economical ways. Maker further hypothesized that the gifted are individuals "capable of (a) creating a new or clearer definition of an existing problem, (b) devising new and more efficient, effective, or economical methods, and (c) reaching solutions that may be different from the usual, but are recognized as being better than previous solutions" (Maker, 1992ba, p.13).

Components of divergent thinking, namely, ideational fluency and flexibility, have been identified as two major variables in models of creative problem solving (Crabbe, 1982; Hocevar, 1979). In fact, fluency and flexibility scores are assigned to task products on the Torrance Tests of Creative Thinking (1974). Lohman (1989), in examining the literature on recent theories of human intelligence, found persistent evidence that individuals rarely solve problems on spatial tests in the same way. Analysis of student test performance revealed a reliance on more than one process. Furthermore, it was evident that students often shifted to a variety of strategies, such as the generation and transformation of a mental image, to solve problems on tasks of figural comparison that increased in complexity. More recently, Clasen, Middleton, and Connell (1994) conducted a study using a nontraditional approach to the assessment of artistic and problem solving in minority and nonminority sixth-grade students. Performance measures of contextual problem solving were assigned fluency scores (total number of solutions) and flexibility scores (the number of solution categories). Fuchs-Beauchamp, Karnes, and Johnson (1993) have recommended that studies investigating originality and imagination need to more closely examine divergent thinking and the relationship between creativity and intelligence in preschool age children.

Research into analogical reasoning suggests that the gifted can be differentiated from nongifted individuals in their use of a variety of processes and cognitive problem solving strategies (Sternberg, 1981). Sternberg and Davidson (1986) described three components of superior human cognitive problem solving: (1) metacognitve skills used for decision-making in problem solving; (2) performance processes such as inference; and (3) the knowledge acquisition or skills used in analyzing and synthesizing new information, memory, and transfer processes. Based on observations of children, the researchers concluded that highly able individuals use a variety of processes and cognitive strategies to solve problems.

Limitations of the Studies

Surprisingly, the literature search yielded only two relevant studies concerning the problem solving of young gifted children. Renfrow (1985), in her doctoral dissertation, used quantitative methods of statistical analysis (i.e., discriminant function analysis and t-tests) to investigate elements of problem solving used by young high ability children accepted into a special program for gifted students and high average ability children not accepted into the program. Participants in the study were required to solve a variety of non-routine problems. In her study of 5 to 8 years olds, who were assigned into two groups based on IQ scores, she found that quantitative differences in performance on measures of cognitive style and problem solving were statistically nonexistent. She concluded that the two groups of children did not differ significantly on any of the variables measured. Thus, the two groups appeared to be more homogeneous than heterogeneous in their performance on measures of hypothesizing, analogical/numerical thinking, and planful behavior in relationship to performance on measures of cognitive style.

Kanevsky's (1990) study provided contrary evidence of age and ability-related differences in the learning and flexible use of problem solving generalization of young children. She relied on both quantitative and qualitative methods to analyze the problem solving strategies and learning of average and high ability 4 to 8 year old children. She divided participants into four groups according to chronological age and IQ scores. More specifically, she designed an interactive assessment environment to explore differences in the children's learning of a problem solving strategy on a modified puzzle task (manipulative) and generalized to a similar but different version (computerized) of the same task. Quantitative comparisons of the learners' performance on the two tasks revealed significant differences in the degree of change in performance from the first problem solving task to the second version of the task. Thus, she concluded that the groups generalized their learning from task to task differently depending on cognitive ability, age, or both. Moreover, several learning and problem solving behaviors were found that differentiated the high ability children from the older, average ability children. First, the children in the high ability group appeared to have a more accurate understanding of the problem. The high ability children were less likely to decline hints, appearing to be self-confident, preferring to find their own problem solution. Secondly, the high ability children learned more from their rule violations. In fact, the 4 to 5 year old high IQ learners were superior to their older mental age mates in their understanding of rule errors and more accurate in their explanations of them. Regardless of age, the high ability children demonstrated differences in their interpretation of the experience in breaking a rule, appearing to understand and learn more from their illegal moves. Finally, analysis of spontaneous comments about the similarity of the solutions to the two problems revealed that the high ability children were more sensitive to finding patterns as they learned the task and more frequently recognized similarities between the two tasks. Kanevsky concluded that the analyses of the generalization variables (i.e. hint use, understanding and violation of rules, and recognition of task similarity) provided evidence of the existence and the nature of age and ability related differences in the generalization of a problem strategy among young gifted children. Table 4 is a summary of the studies of ability differences and the problem solving and young children.

Limitations of the Studies

The search of the literature yielded only two studies treating the topic. Critical of reliability and validity for the instruments used to measure general intelligence and to measure specific aspects of problem solving ability in the samples studied.

Renfrow (1986) studied quantitative differences in children's performance on a battery of nonroutine problems and cognitive style measures. She included an adequate description of purpose and delineated the specific test procedures for each; however, she failed to report reliability coefficients on the measures of nonroutine problems, namely the Stanford-Binet Problem Solving Battery and the Hypothesis Testing Task. Similarly, she did provide the statements of reliability and validity for the cognitive style tests. The battery of tests used in the study were administered entirely by the researcher, yet intra-reliability measures were not reported. Furthermore, Renfrow did not provide clarification

Table 4. Summary of Problem Solving and Young Gifted Children

Study	Participants	Tests/Tasks	Design Analysis	Conclusions
Kanevsky (1990)	Group 1: 20 young average ability children; 4 years 10 months of age Group 2: 22 young high ability children; 4 years 11 months of age Group 3: 22 older average ability children; 7 years 10 months of age Group 4: 25 older high ability children; 7 years 10 months of age	Two versions of the Tower of Hanoi Puzzle: Task 1 - The Monkey Cans Game (manipulative) Task 2 - The Layer Cake Game (computerized)	Quantitative and qualitative analyses ANOVA Frequencies and percentages of selected behaviors	Qualitative differences were noted in the flexible use of problem solving strategy by young high ability children; these children were superior to those of older children of the same mental age.
Renfrow (1986)	Group 1: 20 superior ability, 5 to 8 year olds accepted into a program for gifted students Group 2: 20 above average 5 to 8 year olds not accepted into a program for gifted students	A battery of cognitive style measures and nonroutine problems: The Children's Embedded Figure Test Matching Familiar Figures Test A Test of Ideational Fluency Stanford-Binet Problem Solving Battery A Hypothesis Testing Task	Functional Analysis t-tests	Performance differences between the two groups of children were limited and small; they did not differ significantly on any variables.

of the issues raised in her investigation.

In the study by Kanevsky, two versions of the Tower of Hanoi Puzzle were modified in a study of qualitative differences in the flexible use of a problem strategy by study participants. The Monkey Cans game (manipulative) and the Layer Cake game (computerized) tasks were administered, videotaped, and analyzed both quantitatively and qualitatively by the investigator. Although the purpose and procedures of the two tasks were adequately described, the reliability and validity of these tasks were not reported. Moreover, Kanevsky failed to report intra-rater reliability measures in the administration of the tasks used in her study. Kanevsky (1990) found qualitative differences in the observations of young children who have reportedly dissimilar ages and levels of general intelligence.

Renfrow and Kanevsky provided detailed information about the ages and IQ scores of the participants; however, neither investigator included important demographic information concerning the socioeconomic or cultural/ethnic backgrounds of the respective populations. Small sample sizes were found, also. In the Renfrow study participants consisted of a total of forty children from a suburban school district who were nominated to participate in the district's program for gifted students. Her sample was further divided into two subsamples of twenty. Thus, the groups of participants in the study were formed solely on the basis of IQ scores and not necessarily on skillful problem solving or based on a balance of group membership by sex or age. The sample size in the Kanevsky study was larger (N=89) in comparison to that of the study by Renfrow (N =

40). Kanevsky further divided the sample into four subsamples of 20 to 25 participants based on their IQ and age. In a similar fashion, Renfrow further subdivided the sample into two subsample groups (Group 1: n =20, 14 boys, 6 girls; Group 2: n = 20, 7 boys, 13 girls). Thus, the subsamples in the two studies are the actual units of comparison. The review of research about the nature of the problem solving processes of young gifted children and the ways in which these learners solve and find problems is a confused, contradictory picture that is rather sketchy at best.

Theoretical Framework: Spatial Intelligence and Young Children

Howard Gardner, in his theory of multiple intelligences, proposed that the core operations of an intelligence are inherently different. He described spatial intelligence to be a human competence that is "object based" and bound to the concrete, physical world of objects and the their location in one's surroundings (Krechevsky & Gardner, 1994). Gardner (1983) surmised:

> Central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli. One can be asked to produce forms or simply to manipulate those that have been provided. These abilities are clearly not identical: an individual may be acute, say, in visual perception, while having little ability to draw, imagine, or transform an absent world (p. 173).

In Gardner's view, then, the spatial domain is an area of human intelligence that is considered to be "of a piece" or combination of special cognitive abilities that operate as a family. Furthermore, he maintains that practice in each ability may reinforce skills in other related abilities. Spatial imagery is just one example of a distinct ability researchers have found important to visual-spatial thinking. The ability to solve problems that require mental imagery is unique from linguistic or logical-mathematical ability. In his review of major sources of the literature on the role of the right hemisphere in spatial processing, Gardner concluded that (1) the right hemisphere of the human brain is more important to problem solutions than the left hemisphere; and (2) the posterior portion of the right hemisphere is most involved in spatial processing.

According to Gardner, spatial intelligence can be recognized in how individuals with gifts and talents perceive similarities and understand shapes, spatial patterns, and images in two or three dimensional ways, as do sculptors, artists, poets, writers, engineers, architects, navigators, carpenters, pilots, mechanics, scientists, mathematicians, and computer technicians. In some cases, however, individuals with high competence in the musical or linguistic areas may experience difficulty in the spatial thinking process. Moreover, he argued that competence in the spatial area of intelligence can develop in individuals with visual impairments or other disabilities. He concluded that spatial intelligence is a separate domain not exclusively tied to any particular modality. Similarly, results from the Project Spectrum research lend support to the belief that individual profiles of the intelligences can be identified in children even as young as 4 years old (Krechevsky and Gardner, 1994) . In addition, Gardner and colleagues provided evidence to support the belief that the working styles of young children enrolled in the Project Spectrum program can be assessed and identified within the context of meaningful daily activity. They define working styles as a child's persistence, attention to detail, and level of confidence. Gardner and colleagues contend that a child's working style appears to be content and domain specific. Consequently, a four year old child's assessed competence and working style in the spatial area of intelligence, for example, may emerge only in an area of strength.

Gardner (1983) delineated four core capacities of spatial intelligence: (1) the ability to recognize instances of the same element; (2) the ability to transform or to recognize a transformation of one element into another; (3) the capacity to conjure up mental imagery and then to transform that imagery; and (4) the capacity to produce a graphic likeness of spatial information.

Gardner asserted that aspects of these four capacities are important to orienteering, involved in object and scene recognition, and used when working with drawings or maps depicting the physical world. Sensitivity to lines of force to create a feelings of tension, balance, and composition in a painting or sculpture requires abstract aspects of the spatial domain. Likewise, the ability to use metaphor to represent spatial form in an essay or to depict real-world images of scientific concepts are facets of problem solving using spatial modes of thinking. In fact, Gardner provided many examples of highly developed spatial capacities (e.g. ability to notice fine detail, keen visual memory) and skills (e.g. high degree of spatial acuity, highly developed navigation) observed in contextualized settings (e.g., work, game activities) of specific non-westernized cultures. Thus, Gardner underscores the importance of the influence of a child's culture on the development of these capacities of the spatial domain.

Gardner (1991) and colleagues of Harvard's Project Zero conducted a naturalistic study of domain-specific symbol systems (i.e., drawings, clay modeling, block building, pretend play) engaged in by young children. This study provided insights into several aspects of development related to children's construction of meaning through mostly non-linguistic symbol systems. Concerning the properties in the symbolic development of the spatial domain, Gardner (1991) stated: "In three-dimensional constructions, the capacity to master and vary spatial layout turns out to have stream-like properties. Even in the neighboring domain of two-dimensional depiction, learning the properties of line, contour, and color arrangement has no evident relationship to milestones in other domains" (p. 74). Consequently, the investigators maintained "waves" as a metaphor to depict four patterns of development in each of the "streams" or domains at year long intervals beginning around age two and ending around age 7. These waves of spatial understanding and use are less regular than the properties of a specific domain. Moreover, they claim the ability to understand and appreciate spatial relations within each wave spills over or is mirrored in other domains of symbol use. A summary of the waves of early symbolization as described by Gardner (1991) are presented in Table 5.

Summary

From the review of the relevant literature, no convincing evidence can be found to

Table 5. Summary of Waves of Early Symbolization

Series	Age of Occurrence	Label for Symbolic Capacity	Description	Spatial Representation
First Crest of wave	18 months to 2 years old	Event or Role Structuring	The child is capable of using language in symbolic play to demonstrate her knowledge of the existence of events, that the events involve other persons, actions, and objects, and that the events have consequences.	The child is unable to draw a picture of car driving down a road, but is able to appreciate spatial relations of an event, through symbolic play. She depicts the moment of this event by pretending to drive the car by making physical gestures with object in hand while verbalizing "Vroom, Vroom".
Second Crest of Wave		Topological Mapping	This form of symbol use can be observed in the two and three dimensional graphic representation of clay configurations. In this symbol, the child is able to depict the general yet dominant spatial relations (i.e., size, shape, which corresponds to a real world referent.	The child is able to draw two circles, one on top of the other, to represent the head and body of a person. Similarly, she can spatially represent a house out of a row of blocks (horizontal) and place a triangular block on top of the block construction

Table 5. Summary of Waves of Early Symbolization

Series	Age of Occurrence	Label for Symbolic Capacity	Description	Spatial Representation
Third Crest of Wave	4 years old	Digital Mapping	This form of symbol mapping can be observed in the first time ability of a child to precisely count numerical groups of objects and appreciate spatial relations of the same kind of object or instances of a different kind of object. This appreciation of symbols goes beyond that of the size and shape of object quantities.	The child desires and is able to count the facial features of her drawing or in her block construction.
Fourth Crest of Wave	5, 6, or 7 year old	Notational or Second-Order Symbolization	This form of symbol mapping can be observed in the child's ability to devise notational behavior or scheme to help them remember relevant information. This marks the beginning of the invention of a symbol system that in and of itself refers to other symbol systems. Additionally, the child exhibits a sensitivity to and can make differentiations among kinds of symbolic systems.	The child will invent a tally system to keep track of her progress in a game. The child can readily distinguish writing from drawing. Also, the child can differentiate among kinds of drawings of real-world depictions, such as maps, cartoons, and designs.

support the belief in reliable sex differences in the spatial abilities of children under the age of 11 years. In contrast, of the cultural studies reviewed include evidence of the existence of distinctive patterns of performance on tests of spatial cognitive abilities and related skills in young children from a traditional Chippewa Indian heritage and those from traditional Asian heritages (i.e., Japanese, Chinese-American). The results of these studies provide evidence that differences in spatial abilities exist and appear to be more well developed in the young children of the cultural groups studied.

Less clear, however, are the findings related to the nature and existence of differences in the problem solving strategies employed by young high ability children. At present, the problem solving strategies used by young gifted children are not fully understood nor clearly defined. Indeed, further investigation is warranted to determine if young children of varying cognitive ability demonstrate significantly superior performances on valid and reliable measures of problem solving compared to children with average abilities. Similarly, individual differences in the cognitive processes involved in skillful problem solving and problem finding by highly competent young learners deserves more in-depth investigation.

Clearly, a paucity of current research in the topics treated in this review of the literature exists. All of the studies reviewed were based on recent cognitive theory, relevant research findings, or current theories in the education of gifted students. However, a number of the studies reviewed are limited by problems inherent in the design.

Several criticisms can be made against the studies included in this review. First, few of the researchers have sampled a substantial number of young children across a variety of minority or tribal populations. Second, few of the researchers included a large number of preschool age children in their samples. Third, several of the researchers analyzed and reported effect size statistics according to the sample size rather than the true, smaller subsample size. Fourth, most of the researchers treated spatial abilities as one single ability rather than as a number of abilities that are interrelated. The construct of spatial abilities is elusive, complex, and ill defined. The literature base in these areas is deficient and in need of more in-depth investigation to determine patterns of cultural difference in the spatial abilities of young children. The same can be said for the determination of differences in the problem solving processes employed by young children with high potential or superior cognitive abilities.

In Gardner's theory of multiple intelligences, spatial ability is broadly defined as a combination of many independent but interrelated unique cognitive abilities that operate as a family. In his view, spatial intelligence is a separate domain not exclusively tied to any particular modality. He maintains that practice in each ability may reinforce skills in other related abilities; however, this is dependent on the value that is placed on these abilities by the cultural and social institutions to which a young child belongs.

Gardner and colleagues provided evidence that individual profiles of the intelligences can be identified in children even as young as 4 years old. Moreover, the spatial area of intelligence, among others, can be assessed and identified within the context of meaningful daily activities. Thus, the findings from Harvard's Project Zero and Project Spectrum, though tentative, do shed light on the understanding, development, and assessment of spatial intelligence in preschool-age children.

CHAPTER 3

METHODOLOGY

Design

This is a multiple case study of spatial problem solving abilities and the characteristics of products created by eight young children on a performance-based assessment (Maker, Nielson, Rogers, & McArthur, 1996). This assessment was administered in two separate pre-kindergarten classrooms prior to an intervention program. The application of task analysis case study methodology (Moon, 1991) to inquiry was selected for this project for several reasons. First was the ability to provide distinct, detailed, and intensive descriptions of the behaviors that could be observed and the products created by individuals on a problem solving task involving spatial intelligence. Two other considerations were (1) the ability to determine the existence of qualitative differences and spatial competence between female and male students enrolled in a special bilingual enrichment pre-kindergarten program; and (2) the ability to determine the existence of culture-related differences and spatial competence between Hispanic students and Navajo students enrolled in similar bilingual enrichment programs for young children with limited proficiency in English. Finally, methods of task analysis were used to generalize the in-depth case descriptions to those of other cases to expand upon the understanding of the domain of spatial intelligence as delineated by Gardner in his theory of human intelligence.

This study is an embedded, multiple case study design (Yin, 1994). The study is considered embedded because it involved two levels of analyses. Analytical generalizations were made about the behaviors and products created by individual preschool-aged children on a performance-based assessment involving problem solving in the spatial area. The larger unit of analysis focused on the detection of individual and group differences in the case study profiles of participants. One subunit of analysis involved the detection of individual differences and sex-related differences in the problem solving behaviors that could be observed and spatial characteristics of the products within each case group, the urban project site and rural project site respectively. Another subunit of analysis involved the detection of culture-related differences in the problem solving behaviors and spatial products between the two groups.

A multiple case design was chosen because the study contained eight individual case studies. In this study, the findings from the single case study and the cross-case comparison conclusions were tied together by Gardner's theory of multiple intelligences. The research design for the case studies followed principles of replication logic. Each case was selected carefully. The researcher studied one single case in-depth. Then successive cases were examined to see whether the patterns found matched those found in the previous case. These cases illustrate the replication approach used in this study (see Yin, 1994). The steps the researcher followed in the design of the present study, from the conceptual definition and the theoretical framework through the process of data collection and analysis are presented in Figure 1. To enhance the reliability of the findings and to guide the researcher in planning the implementation phase of the study, a case study

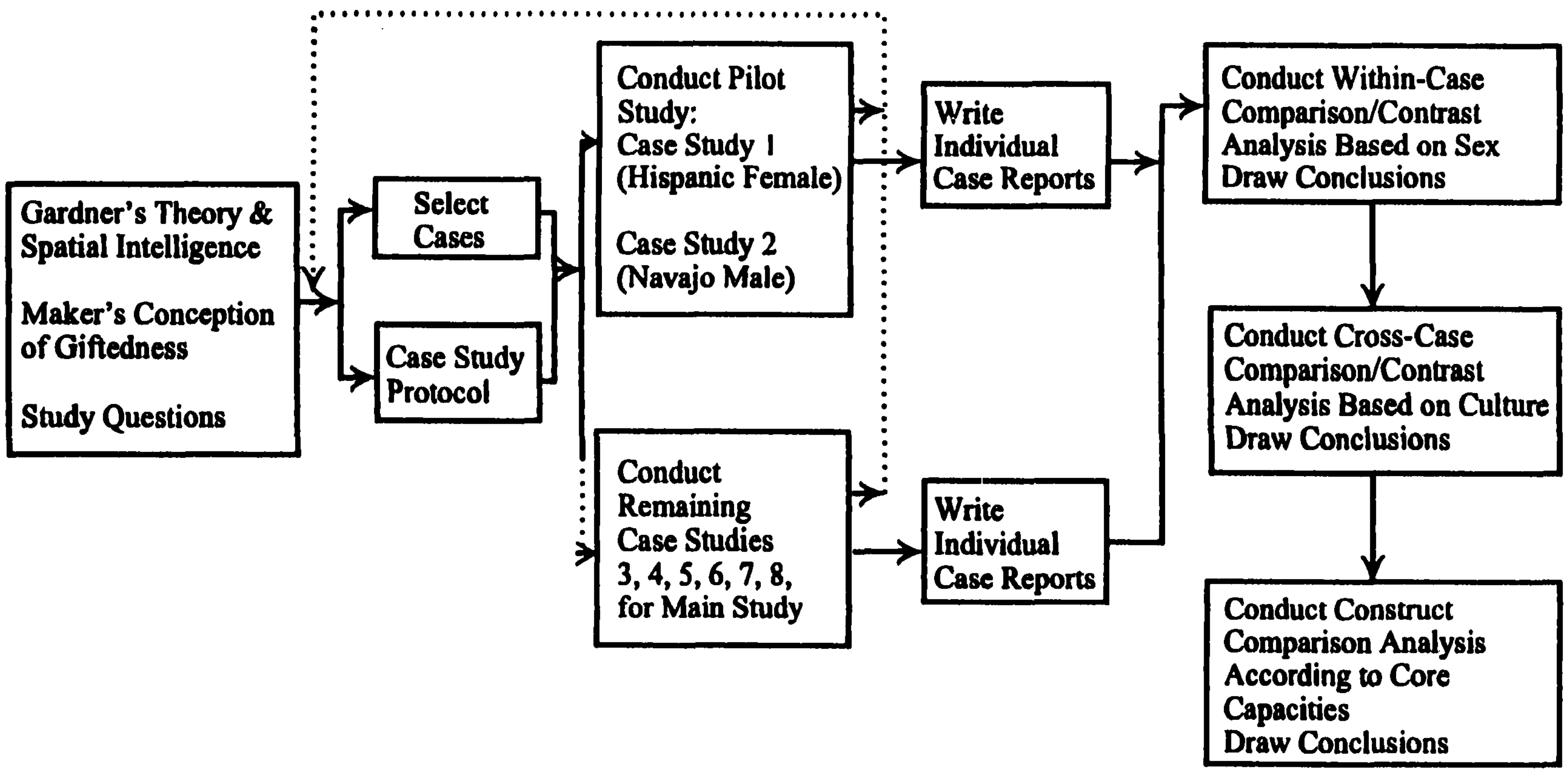

Figure 1. Replication Approach to Multiple-Case Study Method.

protocol (Yin, 1994) was created (see Appendix A for the Case Study Protocol).

The study involved three phases of research. In the first phase, the researcher selected four cases from the Hispanic students participating in the program at the urban school site in a school district in Tucson, Arizona. Four single case studies were conducted (Hispanic-Urban). Simultaneously, the researcher selected four other cases from those participating in the program at the rural school site on the Navajo reservation in Rock Point, Arizona. Four more individual case studies were conducted (Navajo-Rural). The researcher composed a detailed case report for each participant. Data were interpreted and synthesized into eight individual profiles of problem solving on an activity involving abilities in the spatial area.

The second phase of the study involved analysis of participant groups. The data from each of the four single case studies within the Hispanic-Urban group and the four single case studies within the Navajo-Rural group were examined for patterns of sex-related differences. Generalizations about case group shared patterns and conclusions were made along gender lines. Subsequently, the individual profiles across case study groups were examined for patterns of culture-related differences. Generalizations about case group shared patterns and conclusions were made along cultural lines.

The third and final stage involved analysis of all cases. The data from each individual case profile were examined for evidence of instances of the core capacities of spatial intelligence. Generalizations about the individual case reports and conclusions reached about general levels of competence (i.e., children's spatial strengths/interest) were aligned with Gardner's descriptions of the four spatial capacities.

Background of the Study

This study is a small study under a larger research project recently completed by Maker and colleagues at The University of Arizona. Project DISCOVER IV is a bilingual education special populations program funded by the Office of Bilingual Education and Minority Languages Affairs, U.S. Department of Education. The study was designed to provide a developmental bilingual enrichment program for four and five year old children who are potentially gifted or identified as gifted. The project helped minority children to enhance problem solving abilities in the seven areas of the intelligences through experiences with art, science, cooking, music, dance and movement, storytelling, writing, and bilingual instruction.. Additionally, the program was designed as a time when the classroom teachers discovered the special interests of each of the students.

Under the direction of June Maker, Ph. D., the DISCOVER IV pre-kindergarten program was implemented from 1993 to 1996 at two sites in Arizona, one in a large, urban school district, one in a rural, Bureau of Indian Affairs (BIA) contract school. Students qualified as educationally at-risk for the program based on the determination of family risk factors and low socioeconomic status. Priority was given to children who were limited in their proficiency in English. Instruction at the urban school site was provided in English and Spanish. At the rural school site, instruction was given in Navajo and English.

Forty-one students were enrolled in the DISCOVER IV Project classrooms ranging in age from 4 years, 2 months to 5 years, 6 months. Since the mean is the most frequently used measure of central tendency for a distribution (Dinham, 1976), the mean chronological age for the entire distribution was calculated as 4 years, 7 months. Twenty students of varied ethnic identity (i.e., African American, Mexican American, and Pascua Yaqui) were enrolled at the urban program site. The children who participated in this program attended a half day session during the 1995-1996 school year. The majority of students were of Mexican heritage. Half of the students in the classroom were male and half were female. Most all of the students' preferred spoken language was English; however, there were two exceptions. One male student's primary language was determined by his parent to be Spanish. A second male student was considered by his parent to be bilingual in both Spanish and English.

Twenty-one Navajo students were enrolled at the rural program site. In contrast to the students enrolled at the Urban site, these students attended a morning summer enrichment program from June 5 to June 26, prior to entering Kindergarten in August. Eleven of the students were male and the remaining 10 students were female. English was the primary language for 70% of the students. Navajo was the primary language for 24% or five of the 21 students. Only one male student was considered to be bilingual in Navajo and English. As shown in Table 6, the total number of students enrolled in Project DISCOVER IV and the total number of individuals assessed from June, 1995 through July, 1996 at each of the program sites are presented.

An innovative, performance-based assessment process was piloted during the 1994-1995 school year. During the 1995-1996 school year, the Project DISCOVER IV

Table 6. Students Enrolled in the DISCOVER IV Pre-K Enrichment Program

DISCOVER IV Pre-K Program											
	Urban Site 1995-1996 School Year (N=20)						Rural Site Summer 1996 (N=21)				
Ethnic Codes [a]	1	2	3	4	5	Ethnic Codes [a]	1	2	3	4	5
Male	0	0	10	0	0		0	0	0	10	0
Female	0	2	7	1	0		0	0	0	11	0
Total	0	2	17	1	0		0	0	0	21	0

[a] Racial or ethnic identity was determined by parent(s) based on the school district's defined categories.

1 = White/Non-Hispanic
2 = Black/Non-Hispanic
3 = Hispanic or Mexican-American
4 = Native American
5 = Asian, Pacific Islander, or Oriental

assessment (Maker, Nielson, Rogers, & McArthur, 1996) was implemented at both program sites (see Appendix B for an overview of the DISCOVER IV assessment and a description of the Spatial Problem Solving Activity). Most of the children were videotaped and carefully observed in the classroom by the teacher and trained observers on the DISCOVER IV Assessment Team prior to the intervention program.

Pilot Study

The pilot study provided the researcher with a satisfactory plan for conducting each single case study. The purpose of the pilot study was to prepare and delineate data collection, reduction, and analysis procedures to be followed in the main study. Phases of the pilot study included selecting the units of analysis, determining the method of case selection, delineating the data collection procedures, developing the coding instrument to be used in the analysis of data for each separate case study, and developing and finalizing the data collection and case study analysis forms. Consequently, the researcher was able to improve upon the preliminary conceptualization of the single case-study design delineated in the case study protocol.

A purposeful sampling technique (Bogdan & Biklen, 1992; Rogers, 1993) was used to select participants whose videotapes were analyzed. This technique allowed the researcher to include two participants for the pilot study, one from each of the program sites.

Participant Selection Procedures

The participant pool selection procedure involved several steps. Three sets of criteria were established to guide participant selection. Ethnicity, gender, and high spatial competency based on classroom teacher determination were considered in the final selection of participants for the main study.

Criteria for the initial step included (a) the participant's ethnicity is either Hispanic or Navajo; (b) the participant's chronological age at the time of the assessment was between four years, zero months and five years, three months; and (c) a videotaped recording of the DISCOVER IV Spatial Problem Solving Activity were stored and available for viewing by the researcher.

The next step of participant selection was to determine the quality of the videotaped recordings made at the time of the assessment. These criteria included (a) a clear view of the participant during the assessment activity; (b) a clear view of product(s) created by the participant; and (c) audible responses of the participant in either English, Spanish, or Navajo or audible response of the participant on the audiotape accompanying the videotaped session. Participants whose videotapes were determined useable formed a participant pool. Six Hispanic students were eligible to be included in the urban site participant pool. Twelve Navajo participants were eligible to be included in the rural site participant pool. Thus, a total of eighteen participants were deemed eligible. Participants in the urban site selection pool ranged in age from 4 years, three months to 5 years, 0 months. Participants in the rural site selection pool ranged in age from 4 years, 6 months to 5 years, 1 month. The gender, chronological age, and primary language of the total participants eligible to be selected for the main study are presented in Table 7. The third

Table 7. Eligible Participants Selected During the Pilot Study

	Urban Site						Rural Site					
Participant	1	2	3	4	5	6	1	2	3	4	5	6
Gender[a]	F	F	F	M	M	M	M	M	M	F	F	F
Age	5-0	4-11	4-3	4-10	4-5	4-4	4-9	4-7	5-1	4-11	5-0	4-10
Primary Language[b]	E	E	E	E	E	S	N	E	N	E	E	N

[a]E = English; N = Navajo; S = Spanish
[b]F = Female; M = Male

and final step was to select four participants from each of the two participant pools. Thus, eight participants were selected for the main study.

The first phase of participant selection was to use a simple random sampling procedure to select two participants to be included in both the pilot study and the main study. The researcher randomly selected Case Study 1 from the Urban Site participant pool and Case Study 2 from the Rural Site participant pool. Pilot Study Case 1 was a five year old Hispanic female whose primary language was English. In contrast, Pilot Study Case 2 was a Navajo bilingual male who was four years nine months of age.

The second phase of the main study participant selection process was to apply two selection criteria: high spatial competency and gender. First, Case 1 was chosen as the participant with high spatial competency from the Urban Site participant pool and Case 7 was chosen from the Rural Site participant pool. Coincidentally, Case 1 and Case 7 were 5 year old female students. They were the only students in each of the two project classrooms to be recommended by their teachers for the special kindergarten program for the gifted. Once again, a simple random sampling procedure was used for the final selection of participants for the main study. Case 3 was selected as the additional female participant and Cases 4 and 5 were selected as the additional male participants from the Urban Site. Lastly, Case 6 was selected as the final male and Case 8 was selected as the final female from the Rural Site participant pool.

Data Collection and Analysis

Data coding and analysis procedures were interwoven throughout all stages of the pilot study. Initially, a physical filing system was set up for the storage and retrieval of videotapes and the observation write-ups and summary for each case study. Second, a computer software program was selected to facilitate ease in the coding of case study transcripts and archival documents. Folio VIEWS, Version 3.1 (Folio Corporation, 1996) was chosen as the data management system on the basis of cost factors, program characteristics, and the nature of the overall project (Miles & Huberman, 1994).

An observational system was developed for purposes of data collection, data reduction, and data analysis. The researcher designed and formatted the Video Observation Write-up, the Coding Reliability Check form, the Case Study Document form, and the Spatial Activity Summary form. Next, descriptive data were collected and coded for behaviors observed and product characteristics for Case 1. Initially, the videotape was viewed with the sound off. The researcher indicated on the Video Observation Write-up sheets exactly what the participant did and what the products looked like, and avoided making inferences about the behaviors observed (Rogers, 1993). Following the same procedure, the researcher viewed the Case 1 videotape a second time with sound on. The descriptive data were recorded on the Video Observation Write-up form, reviewed, and corrected. Next, segments of the text describing behaviors and product characteristics were (a) coded and sorted into the predetermined code list of categories outlined in the case study protocol; (b) titles for each category were modified; and (c) the categories were sorted within to determine subcategories.

Next, a member of the Project DISCOVER IV Research Team, who was unfamiliar with the design and purposes of the study, was hired by the researcher to assist in the early stages of data collection and analysis, and the refinement of the individual case study forms, coding instrument, and code definitions. Videotapes of each participant engaged in the spatial activity of the assessment process were viewed by the researcher and her research assistant.

While simultaneously viewing the videotape of the female participant (Case 1), we individually coded behaviors and products created to determine recording consistency. We compared data recorded on the Video Observation Write-up form and returned to the videotape whenever inconsistencies were found (Rogers, 1993). Several revisions of the video observation write-up form were tried again for Case 1 before the data collection and reduction procedures and guidelines were clearly delineated. On the top of the revised version of the Video Observation Write-up, we keyed the form as to the participant's age, gender, cultural background, and project site. Next, we read, reviewed, corrected, and coded our observation write-up. Then, we completed the Spatial Activity Summary form. We attached this summary form to our video observation write-up to be placed in the case file.

Subsequent steps included (a) carefully viewing the videotapes (in the female case for a third time) to record participants' behaviors and products on the revised Video Observation Write-up; (b) analyzing the case study data for expression of the core capacities of spatial intelligence; (c) viewing the videotapes yet again to determine the total time each participant needed to complete the spatial problem solving activity; and (d) revising the Video Observation form once again after completing the procedures for Case 2. The researcher refined the final version of the data collection and analysis forms to be used in the main study (see Appendix C for the complete set of forms developed in the Pilot Study). Finally, the data in each case file were transcribed by the researcher using FolioVIEWS.

From the Video Observation Write-up and Spatial Activity Summary forms completed on Case 2, a list of codes for patterns that emerged from the data text were recorded and added to the pre-determined coding list used in the coding of data for Case 1. The researcher determined general categories gleaned from the data collected for Case 2. These categories were clarified, expanded, and refined. Subcategories were delineated. The researcher revised the initial coding instrument. Additionally, definitions of codes were developed, clarified, and listed.

Intercoder reliability was measured by dividing the number of agreements by the total number of agreements plus disagreements, times 100 (Miles and Huberman, 1994; Rogers, 1993):

$$\text{reliability} = \frac{\text{\# of agreements}}{\text{total \# of agreements + disagreements}} \times 100$$

The researcher calculated an initial intercoder reliability of 86 % on the Video Observation Write-up and Summary forms on Case Study 2. After discussion of disagreements between the researcher and her assistant concerning differences in the observation of an unintentional problem and determination of a stage of product development, the interater reliability was recalculated at 96%. Consequently, the researcher and the research assistant discussed and refined the behavior codes and the coding definitions to strengthen between-coder reliability.

The researcher met with a colleague to critique and finalize the coding instrument and to evaluate the accuracy of the descriptive summary statements made about Case 1. In general, the evaluator determined the summative statements about Case Study 1 to be an accurate, thorough portrayal of the participant's problem solving and spatial abilities, despite some disagreement with particular judgmental phrases used by the researcher in writing her interim case report. Specific recommendations were made to assist the researcher in revising the descriptions of the physical behaviors and problem solving methods observed. Additionally, several suggestions were given to clarify code list categories and definitions. This evaluation was the basis for the final revision of the spatial problem solving coding instrument. The revised coding instrument became the tool used to classify behaviors and products recorded from videotapes of all remaining participants in the study. The revised spatial problem solving coding instrument, definitions of respective codes, and the expanded codes of the instrument can be found in Appendix D.

Method of Analysis

A multiple case study design was followed to describe in detail the behaviors observed and products created by individual participants. The study was conducted in parallel with the review of relevant literature. The investigation involved three levels of analysis.

First, to understand differences among cases, the researcher assumed that the cases within comparison groups (Hispanic-Urban and Navajo-Rural) were more or less comparable or similar to one another. The researcher conducted the single case study, for a total of eight case profiles. As shown in Table 8, the steps used in the first level collection and analysis of data to be used in the case study descriptions are displayed.

Second, to understand differences across cases, the researcher made within-case comparisons of male and female participants of the Hispanic-Urban case group. Likewise, within-case comparisons of male and female participants of the Navajo-Rural case group were made. Cases were ordered within each of the case groups according to dimensions of spatial problem solving competence. Next, the researcher completed cross-case contrasts/comparisons of the Hispanic-Urban case group and the Navajo-Rural case group participants.

Third, to understand similarities in participant profiles, the researcher analyzed descriptive data from individual case reports according to Gardner's four capacities of spatial intelligence. Thus, the main variable, the "core capacities", was examined across all eight cases.

Participants

The researcher expanded the participants of the pilot study to include six other participants, matched to the pilot study participants by cultural background and age. Three members of the Project DISCOVER IV Assessment Team videotaped each of the students

Table 8. Summary Design (Single-Case Study) Units of Analysis

Participants								
Case	1	2	3	4	5	6	7	8
Sex	Female	Male	Female	Male	Male	Male	Female	Female
Age	5-0	4-9	4-11	4-10	4-5	5-1	5-0	4-10
Ethnicity	Hispanic	Navajo	Hispanic	Hispanic	Hispanic	Navajo	Navajo	Navajo

Data Sources		
Behaviors Observed	Evaluation of Final Products	Archival Documents
• Video Observation Notes • Spatial Problem Solving Activity Summary	• Video Observation Notes • Spatial Problem Solving Activity Summary	• DISCOVER IV Observer Notes (Pre-K) • Individual Education Plan (IEP) • Teacher Nomination - Kindergarten Program for the Gifted

End Product
8 Individual Case Report Profile of Spatial Capabilities Through Problem Solving

selected for this inquiry. Videotapes of the participants on the linguistic, logical-mathematical, and musical DISCOVER IV activities of the assessment process were excluded from the study. The eight individuals selected for the study were videotaped while solving problems encountered or created on the spatial activity of the assessment process at the respective classroom sites. This allowed the researcher to build upon the pilot study. Thus, the study is a comprehensive portrayal of each of the participants. The spatial problem solving profiles of each of the participants were depicted in a case study report.

Participants were selected from the two pilot study groups of students enrolled in the DISCOVER IV Pre-kindergarten classroom at the urban and the rural school sites. All videotapes analyzed were obtained from the assessment data collected between November, 1995 and July, 1996. Using the selection criteria and procedures established during the pilot study, six more participants were selected randomly from the pilot study participant pools to complete Case Study Group A (Urban Site) and Case Study Group B (Rural Site). Participants were from distinct socio-cultural and geographical backgrounds, yet of similar ages. Participants' ages ranged from four years, five months to five years, three months. Half of the subjects were female, half were male.

In summary, the researcher previewed video tapes that were analyzed during the pilot study. This technique enabled the researcher to select participants specifically on the basis of ethnicity, age, spatial competency, and gender. Participants whose videotapes were determined usable formed the selection participant pool for the Case Study Groups. Thus, eight participants were selected based on the predetermined criteria established for the pilot study to guide participant pool selection. The criteria included (a) high quality of the videotape of the problem solving behaviors demonstrated on the spatial problem solving activity; (b) the chronological age of participants ranged from 4 years, 5 months to 5 years, 3 months; (c) high spatial competency based on classroom teacher recommendation was set to ensure the selection of one participant from each Case Study Group; and (d) the gender of participants was specified to ensure the selection of two female and two male participants for the Hispanic-Urban Case Study Group and two male and two female participants for the Navajo-Rural Case Study Group. In Table 9, the demographic data for participants and the trained observers are presented.

Data Coding

The coding instrument developed during the pilot study was subjected to an additional reliability check. The researcher viewed the videotape of the 4 year, 11 month old, Hispanic female participant (Case Study 3). First, the researcher recorded the descriptive data on the set of data collection forms developed during the pilot study. Secondly, the researcher followed the data reduction and analysis procedures delineated in the pilot study. These steps included: (a) viewing the videotapes without sound to record participants' behaviors and attributes of final products; (b) viewing the videotapes with sound to record participants' behaviors and product characteristics; (c) coding descriptive data as to participant's behaviors and products; and (d) viewing the videotapes again to determine the total time the participant was engaged in the spatial activity. As an

Table 9. Total Participants and Trained Observers - Main Study

Participants				Observers			
Case	Gender	Age	Ethnicity	Gender	Ethnicity	Language	Assessment Date
1	F	5-0	Hispanic	F	White/ Non-Hispanic	English	11/95
2	M	4-9	Native American/ Navajo	F	White/ Non-Hispanic	English/ Spanish	11/95 & 6/96
3	F	4-11	Hispanic	M	Native American/ Navajo	Navajo/ English	6/96
4	M	4-10	Hispanic				
5	M	4-5	Hispanic				
6	M	5-1	Native American/ Navajo				
7	F	5-0	Native American/ Navajo				
8	F	4-10	Native American/ Navajo				

additional step to the above procedures, the researcher transcribed and coded the data using the FolioVIEWS software program. Three days later, the researcher re-coded the transcribed text. Initial agreement was calculated with an intra-coder reliability of 92% on the spatial problem solving coding instrument.

Data Analysis

Data were analyzed systematically using the data collection and single case study analysis procedures developed and tried during the pilot study. Computer-assisted methods were used to transcribe, store, code and retrieve case study data for use in inter-coder rater and intra-coder rater reliability checks. Descriptive case-oriented strategies were employed also in an effort to synthesize multiple cases in clusters with certain patterns (Miles & Huberman, 1994). Master charts or "meta-matrices" were designed to better understand differences among cases. Descriptive data for all eight cases were assembled in a standard format as a means to do cross-case comparison. Additionally, case-ordered descriptive matrices were designed to assemble relevant descriptive data from each case report. A rating criteria was established based on the expanded codes of the coding instrument. The researcher ordered the cases so that differences could be seen easily among High, High-Moderate, and Moderate cases. The cases within the cross-case study groups were ordered according to the main variables being examined in the present study. More specifically, cases were ordered according to dimensions of spatial strengths or levels of competence in the observed behaviors and the quality of spatial features of the final products. Criteria for spatial problem solving behaviors of cases ordered as High included (a) having a spatial plan at the start of the activity; (b) using a variety of implementation and solution strategies; (c) encountering or creating the least number of problems; (d) solving most of the problems in the most efficient and effective ways; (e) demonstrating creativity in problem solutions through block play; and (f) demonstrating a high interest in attention to detail. Criteria for the spatial characteristics of final products for cases ordered as High included: (a) constructing the most complex spatial forms in five or more stages; (b) creating a block construction with varied dimension, interior space, and separated objects; (c) including elements found in art or architecture; and (d) producing a final product that more closely resembles a physical structure or object. Thus, the researcher developed case-ordered displays containing data arrayed case by case according to variables of interest across the broad categories of observed behaviors and the broad categories of spatial characteristics of final products.

To address the four research questions, descriptive multiple cases were summarized for comparison in the following way.

Research Questions 1 and 2

What behaviors are observed in young children engaged in solving problems involving spatial abilities?

What are the characteristics of products created by young children engaged in solving problems involving spatial abilities?

The first-level descriptive data collected for each case study were coded according to the coding instrument and summarized in a written report format. The coding instrument was satisfactory to subsequent, cases thus the categories delineated during the pilot study provided the framework that allowed the researcher to respond to these questions. Eleven categories were extracted from the coding instrument. Five of the eleven categories included behaviors observed. Two other categories consisted of characteristics of final products created by each participant. Four more categories included each of the core capacities of the spatial domain of intelligence. Subsequently, the descriptive data for each of the four cases in the two case groupings were arrayed in case level meta-matrices.

Research Question 3

What differences in behaviors and products are noted within and across participant groups?

Multiple case descriptive data were summarized into sentences or phrases and entered into case-ordered matrices according to the behavior observed and final product characteristics. These cross-case contrasts/comparisons were completed in an effort to understand (1) differences between male and female cases within each of the two case study groups; and (2) differences among the Hispanic-Urban case group and the Navajo-Rural case group. Thus, relevant descriptive data from the eight cases were ordered and arrayed in meta-matrices according to demographic elements of gender and cultural background in response to the third research question.

Research Question 4

How are these behaviors and products similar to the core capacities of spatial intelligence?

As previously discussed, Gardner and colleagues purport that even a child as young as four years old, who is raised in an environment where spatial competence is valued can show instances of the capacities of spatial intelligence. Therefore, in an attempt to understand the core capacities of spatial intelligence more concretely, a construct descriptive matrix was designed. A meta-matrix was designed to assemble relevant descriptive data from all eight case reports. Descriptive statements gleaned from each case report were entered and arranged according to the key spatial capabilities in response to the fourth research question.

CHAPTER 4

RESULTS

In the first part of this chapter are presented the individual case results for Research Question 1 and Research Question 2. The researcher developed pseudonyms for the children in this study. Thus, the names of participants will remain anonymous. To address Research Question 1, the researcher described in detail the behaviors demonstrated by the children while engaged in problem solving on the spatial activity of the DISCOVER IV assessment. To address Research Question 2, the researcher evaluated the products created by the children. The spatial and problem solving behaviors observed were analyzed. A synthesis of the categorical data for each individual case is profiled in this section. In the second part of this chapter are presented the results for Research Question 3. To address this question, the researcher made cross-case contrasts/comparisons to determine if sex-related differences exist. Subsequently, cross-case cultural contrasts/comparisons were made. First, the Hispanic-Urban case group data are presented. Next, the Navajo-Rural case-group data are presented. The case descriptions of two individual children with high problem solving abilities in the spatial area, Cases 1 and 7 respectively, were further analyzed and are presented, also. In the final part of this chapter are presented the findings for Research Question 4. To answer this question, the researcher analyzed the case descriptions to determine if similarities in the behaviors observed and products created by the eight children are evident across Howard Gardner's theoretical proposition concerning the core capacities of spatial intelligence. Examples of participants' behaviors and products are used to further illustrate the findings.

Research Question 1

What behaviors are observed in young children engaged in solving problems involving spatial abilities?

To address the first research question, first-level data were coded according to the five categories of behaviors observed from the Spatial Problem Solving Coding Instrument. The researcher summarized the case data in narrative form detailing the behaviors observed. The coded data for the categories unrelated movements, verbalizations, and expression of emotion were combined into one heading at the end of each case report. Thus, eight individual case reports are presented.

Individual Case Results: Behaviors Observed

Participant 3 (Hispanic female, age 4-11)

Implementation strategies.

Patricia consistently used a number of implementation strategies as part of the problem solving process. She was planful in the sequence and execution of her physical movements. She demonstrated also an understanding of her body orientation within the work space. On several occasions she used her leg or foot as a tool to manipulate blocks from one location to another or to obtain a block beyond her reach. The majority of block manipulations involved the use of both hands to (1) align block forms in a row, and (2) place different shaped blocks within the interior space of the enclosure. Typically, she used one hand to hold and steady a block in place, to reposition blocks, or to realign rows before adding other geometric forms. In addition, she removed blocks from the first product for use in the creation of a second product. On several occasions she moved a block or a combination of blocks by sliding. Tactile exploration of blocks was noted before placement. In these instances, she turned the block from side to side and then felt or scratched each surface.

Patricia incorporated other geometric forms into the spatial design. She made several modifications to the block arrangement. These modifications resulted in changes in the pattern of block forms, the subdivision of the interior space, and in the dimension of the spatial form. Consistent use of other methods were noted, such as trial and error, visual inspection, visual comparison, and rebuilding. In addition, she was found to be systematic in her approach. For example, the product she created involved four basic steps. First, she did a visual search of the work area for a specific block (e.g., wedge block). Second, she rotated the selected block in both hands. Third, she combined blocks in rows to create a closed form or enclosure. Lastly, she added different geometric forms to the interior space. Other behaviors of spatial planning were noted. For example, frequent eye and head movements were observed. At times, Patricia appeared to be comparing the lengths of a specific block to areas of negative space. Moreover, she made the block construction in a spatial way. She added rows of blocks to create an enclosure and then added blocks to the interior space. Thus, Patricia seemed to have a spatial plan in mind when she made the block constructions.

Problem types and solution strategies.

Analysis of descriptive data indicate that Patricia was successful in solving a number of intentional and unintentional problems. Two types of problems encountered involved a concern with the interior space of the enclosure and the inclusion of specific geometric forms (i.e., wedge block, round column) as part of the spatial design. A recurring intentional problem involved the exact alignment of blocks in a row. Less frequently solved were intentional problems related to dimension (i.e., how to increase the width or vary the length) of the spatial design. In general, she used the same kinds of strategies to successfully solve problems. More specifically, she used methods of visual inspection and comparison to recognize, find, add or substitute similar geometric forms into the block arrangement or before rebuilding or rearranging parts of the block construction. Patricia used verbal and nonverbal communication strategies to make the observer aware of the completion of the task. Instances of problem definition, however, were not found.

Unrelated behaviors and expression of emotion.

All of Patricia's physical movements were found to be related to the problem solving process. She was confident in solving problems through block play. She was planful in the sequence and execution of body movements within the work space. She was continually working and intent on creating products having a balanced spatial layout. In addition, the four statements she made to the observer show her positive attitude and high interest in the activity. When asked about her first product, she declared: "I made a house." She resumed a search for a specific block, added it to the spatial form, and then responded: "I doing it. Making it? I'm making it (repeats) because I'm going to put something in it. (She stops working, looks up and makes eye contact with the observer.) Um . . . things. Things that goes to the house". Upon completion of the second product she said: "Look it. (to the observer) It's houses with cows in it . . . and cats and fishes . . . in the water" (Case #3 Video Write-up, p. 12).

Case summary.

Patricia's confidence, persistent involvement in the activity, and candid remarks to the observer reveal spatial understanding and skill in spatial and verbal planning. Thus, case findings support the DISCOVER IV assessment results and IEP summary indicating that Patricia is a child who demonstrates definite strengths in the spatial and linguistic areas. These documents provide further evidence of her interest in art projects and sensory play activities in the classroom. Typically, the elaborate drawings she produced in class shows attention to artistic elements of detail and color.

Participant 4 (Hispanic male, age 4-10)

Implementation strategies.

Jesus was observed to be planful in the sequence and execution of all physical movements. He demonstrated spatial understanding of his body orientation within the work space. Initially, he sat behind the box of blocks facing the video camera. Once he began to build with the blocks, he angled his body orientation in such a way that he could build and still keep the product in full view of the camera. He continued to build as he moved counter clockwise around the block construction. Frequent readjustments in position were made. During the building process, he used isolated parts of his body as a tool. Other instances were noted in which he changed position to match the height of the block construction. Jesus was found to be equally adept in the manipulation of blocks with either hand. Some tactile exploration of blocks (i.e., felt surfaces of block, tapping one block on the surface of another) was noted, also. Frequent eye and head movements were noted.

Several modifications were made to the design of the third product Jesus created. In addition, several transformations resulted in major changes to the spatial layout. First, the five-sided enclosure was transformed into a smaller five-sided form. Second, blocks were layered across the top to create a covered enclosure. He identified this as the "roof" to his "house". Finally, he added many geometric forms arranged in stacks and piles of blocks on and around the exterior of the enclosure to complete the final product. Thus, Jesus was systematic in his approach to planning and creating a spatial form. He showed attention to detail. In addition, verbal planning was noted as a method of choice. For example, Jesus informed the observer about his progress during the development of the third product.

Problem types and solution strategies.

A variety of unintentional and intentional problems were noted, yet Jesus was successful in solving the majority of them. The basis of most of the problems encountered or created, however, were directly related to his attention to the illustration he discovered on the side of the box of blocks present in the work area. This illustration depicted a three-dimensional block construction of a house. The central problem of this activity, as Jesus indicated, was: "How do you make a house? (Repeats) Like this. Let me see that box . . . two of these. I need two of these to make a house. See? (pointing to the box on the floor) Two." Thus, Jesus chose to use this spatial form as the visual-spatial plan for the construction of the third product. Solution categories included frequent changes in body reorientation, problem definition, visual search, visual-spatial comparison, block removal, block rearrangement, rebuilding, and experimentation. Problem definition was one of the most notable of the solution strategies. For example, after many attempts to create the covered enclosure, he queried the observer again, this time asking: "How do you make a roof?" (The observer did not answer the question.) He continued to experiment some more with this part of the construction. When a block fell from this arrangement, he modified the size of the spatial form making it smaller, pushed several blocks not needed to the side, and continued to build by adding blocks on top of the enclosure. Next, he stood up to search for another block, and stated: "I need one more for this side." He resumed building until part of the block arrangement fell. He stood up again, walked over to pick up the fallen blocks, and stated: "Aw! My house fall, huh?" "I put in too much, huh?" Thus, Jesus demonstrated verbal and spatial planning through problem solving while attempting to construct the roof of the house pictured on the side of the box.

Unrelated Behaviors and expression of emotion.

Most of Jesus's physical movements were found to be related to the problem solving process. Three behaviors observed, however, were found to be unrelated to the activity. The first instance occurred just before construction of the third product. Jesus appeared to have a cold on the day of the assessment. At the start of the activity, he informed the observer that he needed to blow his nose. He returned to the assessment area and resumed building with blocks. The second instance involved his discovery of the video microphone located on the floor. Initially, he questioned the observer about the microphone. He moved it from under the box and resumed working once again. The next instance was found to be quite different from the others. After completing the third product, Jesus stood up, walked around the work area, looked in the direction of the classroom, and asked: "Where's Claudia?" Subsequently, he left the work area. He returned immediately once the observer asked him to help her put the blocks back in the box. These instances, though not relevant to the activity, show a strong inclination to move about and a strong interest in others. Evidence of Jesus's interest in problem solving through block play can be found in his goal-oriented actions in the production of his spatial representation of a house with a roof. In addition, the variety of questions and comments made to the observer show how the block construction task, considered as a problem solving process, can involve conscious spatial and verbal planning.

Case summary.

Jesus's spatial understanding, agile physical movements, and interest in building with blocks suggest that he is a child with strengths in problem solving in the bodily-kinesthetic and linguistic areas. Overall, written comments found in the DISCOVER IV assessment and IEP documents correspond with the qualitative descriptions found in the case report.

Classroom activities of interest for Jesus involved movement, tactile exploration with play dough, and investigation of new things.

Participant 5 (Hispanic male, age 4-5)

Implementation strategies.

Analysis of Gabriel's body orientation and positioning within the work space showed spatial understanding. The following account of his actions at the start of the activity provides evidence of Gabriel's sensitivity to the orientation of products in view of the video camera. The observer emptied the box of blocks on the floor. He positioned himself in a kneeling position with his left side facing the camera. He began building the first block construction in the space off to the left of his knee. He wanted the spatial form to be positioned in such a way that the front side of the block arrangement was unobstructed and in full view of the camera. He remained in a stationary position for most of the activity. Not until he began his fourth product did he reorient his body to the right side of the product; this physical adjustment allowed him to place blocks behind the original vertical arrangement. Typically, he fixed his gaze on the block construction as he worked. On a few occasions, he shifted his eyes and head away from the product to look up to the ceiling or over to the observer. He used two hands to build, remove, steady, balance, or realign a blocks and preferred to transfer blocks from his right to his left hand.

Further analysis of descriptive data indicate that Gabriel was organized and systematic in his approach to the task. The spatial forms produced seemed to evolve directly through block play. Thus, he did not seem to have a spatial plan in mind.

Essentially, variations of the same basic construction, a stack with a wide base, were produced. Attention to the detail stacks of blocks was noted, also. For example, he revised the placement of small geometric blocks used to embellish each stack. Methods of visual search, visual-spatial comparison, and experimentation were found. He seemed to be referring to spatial concepts related to stability.

Problem types and solution strategies.

Analysis of the problems and solutions indicate that many problems were encountered and created in the process of product development; however, he was successful in finding solutions to more than half of the problems. Typically, unintentional problems involved the placement of blocks on stacks while intentional problems involved the incorporation of different geometric forms into the spatial layout. Solution categories included block removal, block substitution, rebuilding, or starting over to build another stack.

Unrelated behaviors and expression of emotion.

All of Gabriel's physical movements were found to be related to the activity. Gabriel demonstrated interest in block play, working continuously. He exhibited a quiet demeanor. His interactions with the observer can be characterized as polite and cooperative. In addition, Gabriel's verbal responses, though few, revealed insight into the problem solving process. Initially, he indicated to the observer that he was uncertain about what he had made in the creation of Products 1 through 3. He identified his fifth product, however, as the symbol for a house, and then added: "My mom and dad's house."

Case summary.

Gabriel's spatial understanding, persistent involvement in the task, interest in building many block constructions, and his verbal and nonverbal interactions with the observer suggest that he is a child with strengths in problem solving through the spatial and interpersonal areas. Descriptive information found in the DISCOVER IV assessment and IEP documents corroborate these findings. In addition, these documents indicate an interest in spatial and interpersonal activities in the classroom, namely, computers, building with blocks, and socializing with his peers.

Participant 1 (Hispanic female, age 5-0)

Implementation strategies.

Analysis of Elena's body orientation and positioning indicated a keen sense of spatial understanding. She appeared confident in the way she organized the work space and exhibited a sensitivity to the orientation of her product. She positioned herself seated behind the spatial form leaning over the block arrangement or turning from side to side as she continued to build. She wanted the front of the block construction to face the camera so that others could have an unobstructed view of it. On one occasion, she repositioned her body by scooting herself back from the product. This change in body position appeared to be intentional in that it resulted in extra work space behind the construction she was building. On at least one other occasion, she changed from a sitting to a kneeling position to match her height with that of the spatial form. She was able to make subtle corrections with her body to right an unstable stack of blocks with her chest or to realign a tilting stack of blocks with her leg. Thus, she planned, sequenced, and executed coordinated movements and used her body as tool to solve problems. She exhibited precision in the placement of blocks with both hands. In contrast, however, she rarely placed blocks with her left hand or crossed midline from right to left showing a right hand preference. Frequent eye and head movements were noted, also. She seemed to be able to be quick and systematic in the scanning and analysis of the block construction before searching for a targeted block.

Elena seemed to have a definite spatial plan in mind. She made the construction in a spatial way; it was built larger in the back, tapering to the front as if she were building to the camera. Many instances of verbal planning, spatial recognition, visual-spatial inspection and comparison were found; these methods were used consistently throughout the activity. In addition, she exhibited attention to detail and sensitivity to elements of size, balance, and symmetry in the spatial layout of her product.

Problem types and solution strategies.

Analysis of the problem types and solutions revealed that Elena was skillful in solving unintentional problems. Most problems encountered involved the placement of specific block forms on top-heavy stacks or other detailed sections of the product. On one occasion, the flash of the camera interfered with her otherwise precise, careful placement of blocks. A number and a variety of solutions to problems were evidenced. Most of the solution categories to problems included verbal affirmation, block rearrangement, removal, substitution, and reconstruction. Several instances of visual inspection coupled with verbal acknowledgment ("Oops", "Ah") of her spatial plan were noted. For example, after placing two rectangle blocks, one each of two stacks she said: "I think this is how I like them. Yeah."

Unrelated behaviors and expression of emotion.

Elena appeared to be confident in herself and very interested in all aspects of the activity. Typically, her facial expressions were serious and she was steadfast in her working style. Further evidence of her enjoyment in problem solving through block play was found in her occasional smiles for the camera, voice inflections, and the many unsolicited explanations she gave to the observer. Her frequent verbalizations provided insight into the decisions she made and the rationale for goal-directed actions in the production of one complex spatial form. For example, after searching for and finding two specific blocks she stated: "Here's others. I'm gonna put two on the bottom." Similarly, when the placement of the last remaining block caused all but three columns of the product to fall forward, she declared, "Now I'm gonna make another one." In addition, she seemed to show an interest in the observer. Evidence of her desire to keep her audience informed about her actions can be found in statements, such as the following: "Look it!" (Gazes directly to observer as she stacks blocks) "Now I just got to do it on the sides." Continuing to build she added: "My dad and my mom's in the castle marrying each other." Then, she offered a more specific explanation, "And we're staying at the house but they're not going to get married for a long time." Moreover, she demonstrated a cooperative attitude, often smiling for the camera and on occasion volunteering to help. For example, the observer asked Elena to identify the product at the end of the activity. A concerned, yet polite intonation was noted when she responded: "A castle!. You forgot?" Thus, this was one instance in which she defined the observer's apparent problem.

Case summary.

Elena's sensitivity to self and others in the work space, her interest in creating a spatial design composed of artistic elements and obvious skill in spatial problem solving and verbal planning suggest that she is a child with definite strengths in problem solving through the spatial, linguistic, intrapersonal, and interpersonal areas. The DISCOVER IV IEP and other archival documents corroborate the case study report. In addition, pretend play, computers, and books were noted as areas of interest. Thus, the case descriptions of the participant's profile of observed behaviors support the classroom teacher's decision to nominate Elena for the school district's kindergarten program for gifted students.

Participant 2 (Navajo male, age 4-9)

Implementation strategies.

Douglas sat on his knees throughout the assessment activity. He adjusted his position and body orientation as necessary to view the block construction from a variety of perspectives. Initially, he sat behind the block construction facing the camera. At first when selecting targeted blocks before placement, he did not cross the midline with his right hand; however, this behavior ended when he transferred a block to his left hand and grasped another block in his right hand while placing the two blocks at the same time. He was found to be exacting in block placement and alignment. Frequent visual-spatial inspection was noted after the placement of blocks. Often he made additional adjustments to block arrangements as necessary. Frequent eye and head movements were noted.

Douglas demonstrated a systematic approach to problem solving. He learned from experimentation with cause and effect relationships. One notable instance occurred when he placed a triangle block on the top of the structure he was in the process of building; the block remained stationary and did not slide as anticipated. He fixated his gaze on the block, and then used his finger as a tool to put it in motion. Visual tracking of the block's slow but steady motion down the ramp was noted. Next, he added two same size blocks to the stack, thereby increasing the slope of the ramp. He placed the block once again on the ramp and found that the block slid down with increased speed. Evidence of spatial planning was found. He seemed to recognize, find, and incorporate block forms into the spatial design based on elements of size and shape. A variety of methods were observed, including visual search, visual-spatial comparison and systematic analysis of spatial forms, block exploration, experimentation through block play, and a variety of block manipulations such as rebuilding a specific section, block rotation before trial placement, trial placement of blocks, visual examination of the fit of a block, product modifications and transformation. Douglas clearly made products in a spatial way. First he made rows of blocks to create the back and then the sides of the spatial form. Next, he added more blocks in a row to complete the enclosure, filling in negative space as needed. Finally, he stacked blocks on top of the enclosure, placing specific blocks on top for added detail.

Problem types and solution strategies.

Analysis of the problem types and solutions revealed that Douglas was persistent and creative in solving problems. Half of the problems noted were intentional; most appeared to be related to a specific spatial plan or internal visual-spatial model he seemed to have in mind. He reconsidered his initial placement of blocks, frequently making refinements to block alignment and the orientation of the construction. As already described, problems created were directly related to the functional aspect of the ramp-like structure. Through concentrated attention and experimentation with the slope of the ramp, Douglas was able to modify the structure in such a way that any small block at the top would slide freely down the ramp (see Video Viewing Write-up Notes, p. 5). He encountered a variety of unintentional problems, specifically (1) blocks hidden under the box, (2) the box flap obstructing his search for a particular block located in the box, (3) blocks or sections of the product falling, (4) the inclusion of blocks remaining on the floor, and (5) not having enough blocks available to complete the second product of a corral with a house. For problems 1, 2, and 5, Douglas looked to the observer for guidance since solving several problems required changing the assessment situation. The observer provided the following written account concerning his interaction with Douglas over the situation: "He did not want to put down the corral. I told him that since I took pictures already, he can put it down. He did and then asked for permission to begin again."

Unrelated behaviors and expression of emotion.

Most of Douglas's behaviors observed were found to be related to the activity. He showed attention to the task and was found to be highly goal-directed in his actions. He appeared to be confident in himself and demonstrated high interest in exploration of newly created block arrangements and experimentation in his play with blocks. Additionally, Douglas showed an interest in the observer as a person. This was demonstrated by many smiles and in the frequency of conversations with the observer in Navajo. Evidence of his interpersonal skills and a sense of humor were documented in the DISCOVER IV Observer's notes, also. On several occasions Douglas demonstrated delight in verbal play with the microphone located in the work area. After seeing the observer speak into the microphone, Douglas stopped work on his construction, picked up the microphone, said his name several times, repeated spoken phrases in his first language using the same intonations as the observer. Thus, these findings provide evidence of Douglas's enjoyment and positive attitude about the activity and his interactions with the male observer.

Case summary.

Douglas's confidence and understanding of self and objects within the work space, strong interest in spatial problem solving, and verbal interactions with the observer suggest that he is a child with definite strengths in problem solving in the spatial, bodily-kinesthetic, linguistic, and interpersonal areas.

The case descriptions of the participant's profile of behaviors observed are further corroborated by the descriptive data found in the DISCOVER IV Observer Notes and IEP documents. Bat and ball activities, Navajo stories and songs, music, and conversation were delineated as classroom activities of interest for Douglas. Further analysis of the IEP document and statements related to behaviors observed in the classroom reveal Douglas's skill in solving problems in the spatial area. Frequent instances of building corrals, bridges, and scenes with blocks were found, also. Thus, these findings support the summary of descriptive data found in the case report. Despite evidence of his cognitive profile indicating many strengths, Douglas's name was not one of those included on the list of students nominated by the classroom teacher for placement in the school's kindergarten program for the gifted.

Participant 6 (Navajo male, age 5-1)

Implementation strategies.

Samuel demonstrated well executed physical movements within the work space. A number of deliberate changes in his body orientation and positioning were noted. He seemed confident in his ability to plan, sequence, and execute clockwise and counter clockwise movements (i.e., crawling forward and then reverse crawling) around the perimeter of the block construction. The front of the construction always remained in full view of the camera as he worked diligently around the sides and back section of the construction. Thus, he appeared confident in the way he organized the work space, exhibited a sensitivity to the orientation of his block construction, and demonstrated a keen sense of spatial understanding.

Evidence of two handed placement of blocks was frequently observed despite an apparent left hand preference. Typically, he placed blocks one at a time using his left hand and sometimes his right. Several instances were noted in which he slid a large rectangular block precisely into a space, wide opening, or against the back side of the enclosure. Samuel apparently was concerned about the careful placement of blocks. At times, he was observed using both hands to shadow an unstable stack after the placement of a block and several times to adjust the position and pitch of the ramp. In addition, he visually inspected blocks rotated in space.

Frequent eye and head movements were noted. Samuel often fixed his gaze on the box of blocks as he searched for a block and then immediately returned his gaze to a part or specific section of the block construction. Frequently he was engaged in building, rearranging, or rebuilding specific sections of the block structure. On several occasions, Samuel seemed to be able to visually measure the length or width of a block form with his eyes before exact placement.

Further analysis of descriptive data provides evidence that Samuel was systematic in his approach to the problem solving activity. Several instances were noted in which Samuel compared and analyzed geometric forms systematically and then combined them to create a transformation of a different form (right triangle + right triangle = larger rectangle). Frequent visual comparisons of blocks based on size and shape were made. For example, he often combined large rectangular shaped blocks to create ramps or arches. Likewise, he often used small, different shaped blocks to embellish the tops of prominent attached stacks. Evidence of spatial planning was demonstrated in his ability to recognize, find, and incorporate a variety of geometric forms into the spatial layout. The spatial patterns he created with blocks seemed to be based on artistic elements, whereas the block arrangements he built (i.e., variety of arches) seemed to be based on spatial elements found in architecture. At times, Samuel appeared to be referring to the central concepts of symmetry and asymmetry as he created his complex block construction in a spatial way. Initially, he made a simple enclosure with interior space and then added certain smaller blocks for detail. Next, he developed the height of the enclosure with the addition of three stacks combined with horizontal rows adding more detail to the back section of his spatial form. Apparently, he was building the block construction from the inside out. Much experimentation was noted. He readily engaged in exploration of block forms to construct arches, stacks, and ramps as part of the spatial layout. At first, Samuel constructed a ramp separate from the primary construction. Next, he experimented with variations of this form added as part of the main structure. Later, the ramp was disassembled and excluded as a main structural feature of the final product. Samuel seemed to learn from cause and effect as he invented many block constructions. In these instances it was evident that he was experimenting with balance, dimension, and slope of the construction. On one occasion, he actually uttered "oh" after rebuilding a tall stack of blocks that toppled over. In this instance, he changed the spatial plan by decreasing the height and width of a the tallest stack of blocks before ensuring its stability with the addition of larger blocks to the backside of the arrangement.

Problem types and solution strategies.

Samuel appeared to be a capable solver of problems. He demonstrated a preference for finding his own solutions to problems. Although instances of problem definition were not evident, Samuel frequently solved problems effectively using a variety of strategies. Most notable was his use of visual inspection and visual-spatial comparison/analysis before searching for a targeted block. A variety of block manipulations were found such as block repositioning, block rearrangement, additions, subtractions or rebuilding parts of the whole form, and trial placement of specific blocks or sections. Also, he was found to make many physical adjustments such as body repositioning and reorientation.

Analysis of problem types indicates that Samuel successfully solved the majority of the problems noted. Most of the problems observed were unintentional in nature. In general, the problems he solved were related to the placement or repositioning of targeted blocks, the placement of the ramp, and the inclusion of large rectangular blocks. At times, he appeared frustrated with the flaps of the box interfering with his search for a targeted block. Also, the tight fit of blocks aligned inside the box inhibited the flow of block construction as he worked.

Unrelated behaviors and expression of emotion.

All of Samuel's physical movements were found to be related to the task. He appeared confident as he efficiently solved problems encountered. Spatial exploration through block play was evident. Typically, he was engrossed in the problem solving activity and steadfast in his working style. Several times he smiled for a photo taken of him. He was found to be respectful in his nonverbal interactions with the male observer. Thus, his persistent involvement in the development of a variety of structural features coupled with goal-directed actions provide evidence of his enjoyment in building with blocks.

Case summary.

Samuel's spatial understanding, exploration and experimental play with blocks, combined with his agile movements and strong interest in block construction suggest that he is a child with strengths in the spatial and bodily-kinesthetic areas. Further analysis of Samuel's IEP document indicated strong interest in hands-on activities in the classroom, especially those requiring construction and building. Linguistic and bodily-kinesthetic areas were listed as definite areas of strength whereas the spatial area was identified as a probable area of strength. Although strengths in Samuel's verbal abilities were not observed during the activity, the case report depicting Samuel's profile of behaviors observed is generally supportive of the DISCOVER IV IEP summary of strengths.

Participant 8 (Navajo female, age 4-10)

Implementation strategies.

Spatial understanding was evident in the analysis of Rachel's body orientation and positioning within the work space. At the start of the activity, she appeared relaxed, seated with hands in lap. Once she began building with blocks, she repositioned herself in a kneeling position situated behind the construction. The front of the construction was clearly in full view of the video camera. Afterwards, she repositioned herself by using both arms and hands, propelling herself backward and away from the box of blocks. This action seemed deliberate as it resulted in the creation of more work space behind the construction. She remained stationary as she worked turning easily from side to side to reach for targeted blocks in the box. Several instances were noted when she arched her body over the construction to put a block in place with great precision. A left hand preference was apparent yet she was equally adept with either hand. At other times, she felt the surfaces or edge of a block with the fingers of her left hand. Frequent eye and head movements were found, as well. Methods of visual inspection and visual-spatial comparison were frequent before the search for and placement of a targeted block or arrangement of blocks in a spatial pattern. Measurement of blocks with eyes was evident before placement in a corresponding negative space in the block arrangement. Most apparent was a fixed gaze as if she were in deep thought or as if she were studying parts of the whole construction. Clearly, Rachel very aware of the observer and others in and around the assessment area. Eye tracking was evident as she followed the observer's movements.

Cooperative nonverbal communication with the observer was noted. She worked continuously, stopping occasionally for her picture to be taken. Active involvement and interest in problem solving was noted. Most evident was an apparent spatial plan. She seemed to be referring to a central theme. Not till the end of the assessment did she identify the construction as the symbol for a horse. Overall strengths in spatial abilities and skillful problem solving were evident in her highly goal-directed actions. Visual-spatial recognition and analysis of blocks based on geometric forms was apparent. Many instances were observed in which she quickly recognized targeted blocks and then combined them into a new creation. This construction was integrated into the main structure later on in the production process. For example, she added a row of three triangle blocks to complete the outline of the triangle; this row was removed and subsequently added to the asymmetrical side of the final product (see Figure 8).

Rachel incorporated all of the blocks into the spatial arrangement. Reference to central concepts of asymmetry, dimension, and geometry were apparent as she constructed her three-dimensional triangular form. Clearly, her product was made in a spatial way. On several occasions, eyes were fixed up to the ceiling, perhaps referring to her spatial plan. Quickly, her eyes returned to the block construction before the placement or removal of a targeted block section. Experimentation with cause and effect relationships in block play was evident as she positioned, then repositioned blocks to produce a most stable column and combination of stacks in ascending order. Verbal planning was not evident as part of the variety of solution strategies during the problem solving process. Frequent exploration with geometric forms was demonstrated. For example, visual-spatial comparison of same shapes of blocks (two right triangle blocks)was apparent before they were combined to make a different spatial form (1 triangle + 1 triangle = square).

Problem types and solution strategies.

Self confident actions were noted as she efficiently solved problems. Clearly, a preference to solve problems on her own volition was readily apparent. Even in the two instances where it was obvious that the observer's movements caused part of her construction to fall, she took charge of the situation, rebuilding the section quickly before resuming her work. A variety of implementation strategies were displayed (i.e., block manipulation, product modification, product transformation) as she systematically solved problems as part of the process of product development.

Analysis of problem types indicates that Rachel successfully solved all but one of the problems encountered or created. A majority of problems observed were unintentional in nature and involved problems related to the arrangement of blocks in tall stacks. Typically, the addition of a larger, wider block to a narrow stack of blocks caused one stack to be top-heavy and fall; however, on several subsequent occasions she caught the leaning stack with one hand thereby preventing it from falling. On one other occasion, a part of the whole spatial form collapsed when she inadvertently dropped a block on a section of the her nearly completed construction. Intentional problems appeared to be related to negative space and the incorporation of larger blocks into the spatial layout. Fluency of several solutions to the same types of problems was demonstrated. She seemed to learn from her initial errors in the placement of blocks arranged in a top-heavy stack. Consequently, she successfully stacked a number of large blocks in an ascending order. Overall, Rachel demonstrated strengths in spatial problem solving.

Unrelated behaviors and expression of emotion.

Rachel's demeanor was poised. Most all of Rachel's physical movements were noted to be goal-directed. However, several times toward the end of the activity she stopped building. On these few occasions, she turned her head, eyes, and upper body in the direction of her classmates. She sat erect, hands in lap, as if intent on listening to comments made by the teacher. Other unrelated movements noted included instances of head scratching, foot touching, and dress straightening.

No unrelated verbalizations were noted. In fact, Rachel was quietly cooperative with the observer. She was very observant; often taking note of the observer's movements within the work space. Spontaneous verbalizations to herself or to the observer were not seen. Rachel uttered a total of two phrases, speaking only when asked. Immediately she responded, "a horsie" and then repeated "horse" when asked again about the kind of product she created. Declarative phrases were provided as a symbol for her spatial representation of a horse.

Case summary.

Rachel's confidence in herself, interest in tactile exploration and experimentation with block forms coupled with her interest in spatial problem solving suggest that she is a child with strengths in the spatial and intrapersonal areas. Although sensory activities were listed as areas of interest, the spatial area was listed as an area of support on Rachel's IEP. Further analysis of the IEP document indicated an interest in play with clay as a medium. Thus, the case report depicting Rachel's profile of observed behaviors is contradictory to the DISCOVER IV IEP summary.

Participant 7 (Navajo female, age5-0)

Implementation strategies.

Dorothea was consistent in her use of a number of implementation strategies such as, product modification, product transformation, physical adjustments, and verbal planning.

Most block manipulations involved precise placement with both hands to reposition blocks and arrange them in alternating patterns in rows. Many instances of sliding, combining, rotating, or matching targeted blocks before placement were noted. High interest in tactile exploration was noted. Frequently she touched the surfaces of blocks with her fingers or pointed to a small area of negative space. Most notable, however, was her ability to size up or accurately measure (with her eyes) the size of a block or length of the opening within a row of blocks before exact positioning. In addition, a sense of artistry was evident in the block patterns she arranged.

Dorothea was an observant child who showed a keen awareness of her spatial surroundings. All of the physical movements observed demonstrated an explicit understanding of space and strengths in spatial planning and problem solving. Frequent changes in her body positioning within the work space were noted. She showed an appreciation of the video camera and the observer as she freely maneuvered in and around the block construction. For example, early on in the process of product development Dorothea worked herself back against the book shelf as she expanded the length of the first block enclosure she built. Obviously, that she had very limited room to move, yet she was able to plan, sequence, and efficiently coordinate her body movements to move herself outside of the space and reorient her body in such a way that the view from the camera remained unobstructed. Similarly, hand and arm movements were found to be purposeful and efficient. Thus, she was equally adept in the use of her hands. Frequent eye and head movements were noted as she visually inspected block forms, made visual-spatial comparisons of parts or whole aspects of each form before searching for and quickly finding a targeted block.

Dorothea exhibited a variety of methods as part of her working style. She showed persistence and demonstrated strong interest in all aspects of the activity. She readily engaged in nonverbal communication with the observer. Many smiles and friendly gestures were noted. Often eye contact was directed toward the observer and the video camera. She was very aware of herself and others (i.e., observer, classmates, her mother and sibling) seeming pleased with their very presence. Dorothea provided the observer with many confirmations about specific symbols of spatial representations as she pointed to segments and separated objects within the construction. In addition, she constructed her products in spatial and bodily kinesthetic ways. She moved freely inside, outside, and around the interior and exterior of her products viewing them from many angles as she worked. Even after the product was finished, Dorothea steadfastly made refinements to the spatial design. For example, she moved two blocks from the interior and placed them on the outside of the enclosure. Later, she commented that the half circle block was a "rock" and the other triangle block was a "swing" attached to the "slide" or covered part of the enclosure representing one of the two bedrooms. Her strengths in spatial abilities are related to (1) the ability to recognize and analyze spatial information in the physical environment (e.g., home, school) through methods of spatial comparison and tactile exploration; and (2) the ability to execute a detailed spatial plan of a house with specific rooms and physical features.

Analysis of experimental block play showed an interest in central concepts related to geometry and art. Many linear forms were noted such as right angles, acute angles, parallel lines, and perpendicular lines were combined to make a large, complex structure that varied in dimension. A most notable theme found in the spatial design of her second product was the repeated geometric pattern of a square (see Figure 7). Furthermore, analysis of descriptive data showed that she made her block constructions in a spatial way. A systematic approach to block construction and problem solving was evident. First, she made an outline by combining horizontal rows. Next, she made a variety of modifications to the rectangular (Product 1) and square-shaped enclosures (Product 2). Finally, she further subdivided interior space, made additions to the interior space, and added some embellishment to the exterior of the enclosure. In addition, "other" behaviors noted show Dorothea's inventive use of blocks and block combinations.

Problem types and solution strategies.

Dorothea was observed to be skillful in her ability to solve spatial problems using a variety of solution strategies such as adjustments of eyes, head and body. Dorothea was highly efficient and effective in solving problems. The majority of the problems observed were intentional and involved problems related to placement of blocks in rows with space or in the interior space of the spatial form. She was experimenting with the negative space. Only two unintentional problems were noted; each involved the repositioning of a targeted block when it was knocked out of place. Dorothea is systematic yet flexible in her solutions to intentional problems. Also, she showed some variety in her solutions to each problem type.

Unrelated behaviors and expression of emotion.

All of the behaviors observed and the verbalizations made were purposeful and relevant to the problem solving activity. Thus, evidence of unrelated behaviors was not found. Dorothea was cooperative and highly interested in every aspect of the problem solving activity. Her frequent smiles, gestures, body posture, eye contact, tone of voice revealed her enjoyment with the activity. Animated interaction with the observer were displayed, also. Not until the end of the activity were verbalizations noted. After she was asked by the observer to tell him about her construction, spontaneous verbal comments were made as she pointed out key features and identified specific rooms for her audience. Frequent smiles and eye contact with the observer were exhibited throughout the labeling process. She pointed to the "house", then responded: "This is the stairs." Dorothea continued to point to objects then rooms inside the interior of the enclosure. Then she pointed and labeled specific features attached to the exterior of the construction.

Case summary.

Dorothea's spatial understanding, steadfast involvement in the activity, and interest in spatial problem solving suggest that she is a child with strengths in the spatial and interpersonal areas.

The case descriptions of the participant's profile of observed behaviors support the classroom teacher's rationale for nominating this student for the school district's kindergarten program for gifted students. Dorothea's skill in spatial problem solving and obvious strengths in interpersonal skills were evidenced in the descriptive case report. Noted as an interest on the IEP document was the drawing of elaborate, often colorful designs. However, the spatial area was not listed as a strength or area of support on the IEP. Further analysis of descriptive comments from the DISCOVER IV assessment and classroom observation notes, however, showed evidence of problem solving strengths in the spatial area. Thus, the findings related to Dorothea's interests and strengths in classroom and assessment activities are similar to the findings from the case report.

Research Question 2

What are the characteristics of products created by young children engaged in solving problems involving spatial abilities?

To address the second research question, the coded first-level data of characteristics of participant final products were synthesized according to the two categories of the coding instrument. The researcher summarized the descriptive data in the following written drafts detailing the block constructions produced by each participant.

Individual Case Results: Product Characteristics

Participant 3 (Hispanic female, age 4-11)

Patricia constructed two final products during the twelve minutes she was observed to be engaged in the assessment activity. She labeled each product "a house". The first product can be characterized as an enclosure (flat) with interior space (see Appendix E, Figure2, Form a). This form had the appearance of a balanced, uniform structure. Also, with the addition of several round column blocks, she subdivided the interior space of the enclosure. Perhaps the intent of this modification was to spatially represent rooms within her final product. Likewise, the wedge block form placed vertically within a wall of the first enclosure may be representative of a roof (see page 4 of the Video Write-up Observation Notes for Case #3). She used a total of 14 blocks. Her form was constructed in two stages. Several minor modifications were made during the process. In the rectangular layout of the first form, she created horizontal rows of block combinations. Within the interior space of the form, she added several blocks to create four subdivisions of space.

Patricia's second representation can be characterized as an enclosure (flat) containing several forms designated as real-life objects within the interior space (see Appendix E, Figure 2, Form b). This form had a balanced more solid, sturdy appearance than the previous form. She used up to 24 blocks but not all blocks contained in the box. Her form was constructed in four stages. The process of product development was simplistic yet more complex when

compared to that of her first product; she made at least four minor modifications and one major transformation. For this product, she used stack and row combinations to create her enclosure. In contrast to Form a, Form b did not have any subdivision within the interior space, perhaps to accommodate different blocks for specific objects designated as animals (i.e., wedge block represents "cow"). The spatial layout of this form was square. She evidenced attention to detail. Observations revealed that she made consistent use of the same blocks in both spatial forms; the three blocks used in her first product to subdivide the interior space were later added as part of the exterior side of her second enclosure, perhaps as added embellishment. Likewise, she made flexible use of different shaped block forms placed within the interior space of her products. These observations may be suggestive of artistic interests that were noted in the DISCOVER IV end of year IEP. Furthermore, analysis of characteristics of Patricia's spatial representations of a house provide clues to an ability to recreate certain aspects of her visual experience (i.e., rooms within the house, blocks representing symbols for pets).

Participant 4 (Hispanic male, age 4-10)

Jesus constructed three versions of the spatial representation he labeled as "house" (See Appendix E, Figure 3, Forms a-c). He was intent on constructing a house with a roof that was similar to the one pictured on the side of the box for the blocks. On several occasions he made known to the observer the fact that he was using this illustration as his spatial plan of reference (Case #4 Video Write-up, pp. 9&10). He was engaged in the assessment activity for a total of thirteen minutes.

The two forms initially created by Jesus can be characterized as a basic stack (see Appendix E, Figure5, Forms a & b). He used a total of 4 blocks to create each stack. The first form was a vertical, asymmetrical stack consisting of four blocks of varying shapes and sizes (Form a). He created the second form (Form b) immediately after the fourth block (wedge block) fell. Jesus's second form combined a horizontal row with a one block stack. Unlike the first form, this one involved two stages of development. First, he aligned three same-shaped blocks to form the base. Next, he centered a long rectangular block on top of the middle block.

The third and final form (Form c) Jesus produced was comparatively different from the other two. This version of a house was constructed with the creation of a roof apparently in mind based on the visual referent he used at the onset of the activity. In contrast, this form can be characterized as an enclosure with covered interior space and pile (combination). He arranged approximately 25 blocks into a combination of vertical and horizontal stacks. This form involved four stages of product development. The first two stages involved his use of rows (horizontal) combined with one stack to create a five sided enclosure (flat). The form resembled a two-dimensional line drawing of a house with a pointed roof on top (Case #4 Video write-up, p. 6). Moreover, Jesus did not subdivide the interior space of his enclosure nor add other block forms to the interior space as Patricia did in her spatial representations of a house. The third stage began with the vertical stacking of blocks. Subsequently, after a part of the enclosure fell, he rearranged the blocks from the now three-sided form into a smaller, covered version similar in shape and appearance to the enclosure described previously. In the fourth and final stage of development, Jesus made one major transformation that changed the enclosure (covered) into a three dimensional enclosure combined with a pile. The tallest vertical stack appeared to be the central apex of his sturdy house; it was representative of the house with a roof that he consistently strived to create (Case #4 Video write-up, pp. 6 & 7).

Participant 5 (Hispanic male, age 4-5)

Gabriel constructed the greatest number of products, five separate spatial representations in all (see Appendix E, Figure 4, Forms a-e). Apparently, he did not have a spatial plan in mind for the first two products constructed (Forms a and b), as evidenced by his initial response to the observer. When asked about what he made, Gabriel uttered: "I don't know" (Case #5, Video write-up, p. 10). Gabriel did initiate the label "house" for the third and fifth products he created. In fact, he explained to the examiner that the third product was "my mom and my dad's house" while the final product was "my house". Thus, the last three spatial forms were indeed different versions of the representation of the house he actually lives in with his parents. Gabriel was engaged in the assessment activity for a total of 16 minutes.

Each of the five spatial forms can be characterized as asymmetrical piles without interior spaces. Each consisted of a combination of vertical and horizontal stacks (Forms a & e) or one single stack (Forms b, c, & d) usually positioned on top of a large square or rectangular (horizontal) form; perhaps his consistent use of this form may be representative of the base or foundation of Gabriel's house. Furthermore, Gabriel completed each taller stack with the addition of a particular block form of similar size (i.e., small triangle, small half circle), perhaps to spatially represent the roof of his house constructions. He used a total of 5 to 8 blocks to create all but his final product. In contrast, the final spatial form (Form e) was comprised of 15 blocks; and incorporated four base blocks with three vertical stacks. The largest and the smallest vertical stacks were arranged on a smaller square block and separated from the two rectangular (horizontal) bases. Moreover, the initial and final spatial forms though simplistic were more complex than the others. In addition, these two products involved four to five stages of development. Gabriel was observed to modify the design of his spatial forms quite frequently. Major transformations were made each of the three times a block fell, a stack began to lean, a combination of blocks slid off, or once when the whole form collapsed (Case #4, Video write-up, pp. 4-6). Finally, analysis of the five spatial forms revealed Gabriel's attention to detail of the design in terms of block selection and arrangement of blocks within vertical stacks. Moreover, he combined artistic elements of balance and geometric shape to create an elaborate spatial representation of the final spatial form (Form e).

Participant 1 (Hispanic female, age 5-0)

Elena constructed one final product. She was engaged in the activity for approximately 16 minutes. She designated her only product to be the spatial representation for "a castle". Elena's spatial form can be characterized as an enclosure (erect) with subdivided interior space and one separated object (see Appendix E, Figure 5, Form a). Her enclosure consisted of a combination of horizontal rows and vertical stacks that varied in size (Form a). She incorporated all of the block forms available into a unified whole. Elena added one separated stack outside the enclosure.

Elena's final product was complex; it involved six stages of development. Several modifications were made to create the enclosure. In the second stage of development, she added two narrow vertical columns comprised of three blocks each (small, square shaped block). This modification produced a balanced, symmetrical appearance of her spatial form. Similarly, the addition of two different wider vertical stacks produced a solid appearance to what would become the front and back sides of the enclosure (Case #1 Video write-up, pp. 5 & 6). Stages four and five of product development provided evidence of her attention to detail and her concern with the overall design of the spatial form. In these two stages, she began to construct the sides of the enclosure with the addition of two smaller columns with a triangle shaped block completing the top of each. Perhaps she embellished the columns with intent to construct towers of a medieval castle, similar to those depicted in children's books of fairy tales. During the sixth and final stage, she added the tallest section of the enclosure with the two large, rectangular blocks. This addition, along with the placement of the remaining eight blocks (small, different shaped geometric forms), was a major transformation that changed the final product from a symmetrical, sequenced series of stacks into an asymmetrical enclosure having subdivided interior space and one separated object or stack (vertical). The design of the spatial form she produced conveyed a sense of artistry. Her flexible use of shape, balance, dimension and sensitivity to detail in the arrangement of all the block forms produced a final product that was a sturdy representation of an "imaginary" castle that was clearly not part of Elena's immediate physical surroundings.

Participant 2 (Navajo male, age 4-9)

Douglas constructed two final products during the eleven minutes he was observed to be engaged in the activity. The first product can be characterized as an enclosure (erect) with interior space (see Appendix E, Figure 6, Form a). Douglas labeled his initial spatial form as "a horse corral". Essentially, his first enclosure was elaborate and contained most of the blocks (approximately 33 in total) that he arranged in combinations of horizontal and vertical stacks. Development of his first product involved a complex process of five stages. During the first two stages, he constructed an asymmetrical enclosure with added detail provided by the placement of three different shaped blocks (Case #2 Video write-up, p. 4). In the final three stages of development, however, he made several major transformations that changed the overall layout of the enclosure. The first modification involved the addition of a functional ramp-like form to replace the front side of the enclosure. Initially, he added blocks to change the height of the stack and vary the slant. Next, he removed the ramp. He replaced it with a wide vertical stack with two small rectangle blocks attached; one block was positioned against the side corner of the stack and the other block was inserted into the opening of the bridge block. This created an enclosure with an opening. Finally, he added a lower, elongated stack to close the latter opening. Two more rows (horizontal) were aligned in a V-arrangement and pointed into the interior space. This transformed the partial enclosure into a six-sided enclosure with interior space (see pp. 5 & 6 of the Video write-up). The modifications made to the original enclosure may have been deliberate striving on his part. The fact that he made several changes to a specific and spatially differentiated part of his product may be suggestive of his intent to represent a gate as a realistic feature of his "horse corral".

Douglas's second product was initiated after the observer introduced a square felt mat as part of the activity. Once the mat was placed next to Douglas's first product, he immediately incorporated the remaining blocks into an arrangement of rows on the edge of the mat. He replied: "horse corral" then added "....and a house" when the observer asked him what he had made. Thus, the second product Douglas constructed can be characterized as an enclosure (flat) with interior space not totally formed that was added to his first enclosure (erect) with interior space (Form a).

Participant 6 (Navajo male, age 5-1)

Samuel produced one final product during the 16 minutes he was engaged in the assessment activity. His elaborate block construction was a complex, spatial representation of a house. He incorporated all of the blocks into his spatial form.

Samuel's spatial form can be characterized as an enclosure (arch) with interior space (see Appendix E, Figure 7, Form a). His enclosure consisted of a combination of horizontal rows, stacks, and an archway (Form a). Samuel incorporated all of the block forms available into a unified whole. He arranged certain geometric forms (e.g., rectangular block, bridge shaped block) to create a single archway. Similarly, he selected smaller geometric forms to complete each of the two vertical stacks and each of the two horizontal stacks (Case Study #6, Video write-up form, pp.5-7).

Samuel's final product was complex with a number of modifications made throughout the eight stages of product development. He was observed to be flexible in his use of selected geometric forms to produce a variety of vertical stacks and archways. For example, he constructed a square stack by combining two small triangle blocks. Similarly, he created several types of arches by stacking horizontally particular geometric forms (e.g. bridge block, long rectangle) on adjacent blocks across the interior space (Video write-up, p. 5). In particular, Samuel attached a different type of arch to the spatial form. He combined a row of two rectangular blocks, two square (flat) blocks, and one rectangle (flat) block into a slanted horizontal stack hinged on a square block (Video write-up, p. 6). One major transformation changed the overall layout of a rectangular shaped interior space into a smaller, less elongated, t-shaped space with three inside quadrants (Video write-up, p. 7). Perhaps this was his way to spatially represent rooms within the house. The final product conveyed a sense of artistry given his sensitivity to shape, balance, detail, and his inventive, flexible use of blocks. Overall, the spatial layout of the form had a powerful, uniform appearance.

Participant 8 (Navajo female, age 4-10)

Rachel created one final product during the twelve minutes she was observed in the assessment activity. She designated her product as the spatial representation for "a horsie". She incorporated all of the blocks into her elaborately designed spatial form.

Rachel's final product can be characterized as an enclosure (erect) with interior space (see Appendix E, Figure 8, Form a). Her asymmetrical spatial form was developed in a five-stage process. Rachel incorporated all of the block forms available into one unified whole.

Several modifications were made to the arrangements of blocks in the design of her product. For example, she added the round column to her original stack, replaced it with a different form (e.g. half circle), only to return it to the initial stack. Other modifications were made to increase the length, width, and height of the enclosure and to remove blocks from the interior space. In addition, two major transformations were made to change the overall spatial layout. Initially, she used a combination of stacks and rows to produce an enclosure (flat) with a separated object inside the interior space. During the fourth and fifth stages of development, however, she made a series of changes that transformed her product from an enclosure (flat) form into an enclosure (erect) with well defined interior space (see Case #8 Video write-up, pp. 5 & 6). In fact, the spatial layout of her product was rather unique. The process Rachel used to stack particular blocks on rows resulted in a triangle-shaped form that had two sides of the same length ascending upward to the tallest stack or apex of the form (Form a). She added particular blocks (round column, half circle, two triangles, and a large vertical rectangle) to one side of the enclosure. Her apparently deliberate choice of geometric forms and patterns may be representative of key features (i.e., horse's tail, mane, and head) of her spatial representation. Regardless of her intent, her placement of particular blocks provided evidence of Rachel's sensitivity to artistic elements of shape and balance.

Participant 7 (Navajo female, age 5-0)

Dorothea produced two spatial forms during the 18 minutes she was engaged in the activity. Both products were spatial representations of a house (see Appendix E, Figure 9, Forms a & b), yet each was quite different in the complexity of its overall spatial layout.

The first product can be characterized as an enclosure (flat) with interior spaces (combination). Essentially, Dorothea's enclosure was composed of an arrangement of rows (horizontal) of approximately 23 similar sized geometric forms (i.e., rectangles and squares). The spatial design was simple, involving two stages of development. Initially, she constructed a vertical stack but quickly transformed the spatial design into an elongated linear form that was similar in appearance to a line drawing of a two-dimensional rectangle. She designated the interior space and adjacent separated areas of the spatial form as representations for a specific room (" the kitchen") and permanent attachments to the interior ("the stairs") and exterior ("the flower house") of the form. Thus, she created recognizable symbols for specific common features of a house that may be found within her physical surroundings or socio-cultural experience. In addition, her first product showed her attention to detail as part of her spatial plan.

Clearly, Dorothea's second form was more spatially complex than to her first construction. This product can be characterized as an enclosure (combination) with two separated interior objects and attached exterior objects (Form b). She readily pointed to and labeled key parts and features of her spatial form. She identified three of the combined interior spaces within the spatial form to be rooms, specifically, "the bedrooms" and "the restroom". She indicated that a specific spatial form was "the door", perhaps to the front of her house, and several small triangle blocks attached to an interior wall were "stairs". She actually indicated that a particular geometric form (half circle block) was the spatial representation for a rock. In addition, she explained that the large rectangle block attached to the side of her original enclosure was "a slide" and that the small triangle placed on top of this form was "a swing". Perhaps the two large wedge blocks, one placed inside the covered enclosure and the other placed in a section of the interior space, were spatial representations for a bed in each of the bedrooms. Likewise, the arch she created may be a passageway connecting bedrooms in the main part of the house, one with its own bathroom. Apparently, Dorothea created recognizable symbols for common objects, as well as symbols for living areas associated with the residence of a family with young children.

The second spatial form she produced was developed in four stages. She used all of the blocks, including those from the former product. Several modifications and transformations were made during this construction. Initially, Dorothea combined vertical stacks and horizontal rows to form a square shaped enclosure with an arch. Next, she used specific blocks to cover and embellish the enclosure (erect) and as separated objects inside the interior space. These additions transformed the spatial form from a flat, square shaped form into a five-sided cube. In stage three, she changed the size of the spatial layout by the creation of additional rows to make two more attached enclosures (flat) and one partially formed enclosure (flat). In the final stage of development, she incorporated the remaining blocks (different sized geometric forms); these blocks were identified as objects (separated or attached) within the interior and exterior parts of her spatial form. The final block (round column block) was used to further subdivide the interior space of the large enclosure.

Dorothea's final product evidenced a sensitivity to line or linear patterns of specific geometric forms. In fact, the final product appeared to have a recurring pattern or theme (four smaller linear squares within a larger linear rectangle) throughout the design of her spatial form (see Case #7, Video write-up, p. 5). Moreover, her flexible use of blocks to create varied dimension within parts of the whole resulted in a complex spatial layout. Perhaps she used the initial enclosure (four large squares arranged as a square-shaped stack) she constructed in stage one of the product as her spatial plan or blueprint for her three-dimensional representation of a house.

Research Question 3

What differences in behaviors and products are noted within and across participant groups?

To address the research question concerning qualitative differences in the behaviors and products of male and female participants from diverse cultural backgrounds, the researcher used case-ordered comparison/contrast methods of analysis (Miles & Huberman, 1994). First, descriptive data from the eight individual case reports were synthesized and arranged in a partially-ordered matrix according to case attributes of sex or culture. Second, the case data were ordered from High to Moderate in a case-ordered meta-matrix. To better understand differences between the two Case Groups, the researcher contrasted the case descriptions of high and low exemplary cases. The qualitative data for behaviors observed and final product characteristics were analyzed separately. Consequently, findings of differences in behaviors observed are presented before the findings of product characteristics. Finally, the data were reduced, arranged across noteworthy categories, and displayed in next-step versions of the initial case-ordered matrix.

Sex Differences and Case Results

Qualitative differences between female and male case groups are not evident in terms of the in-depth descriptive analysis of observed behaviors. Thus, the female and male children in the study do not show qualitative differences in the patterns of behaviors across the spatial abilities, problem solving, or working styles categories. Table 10 is a visual display of the composite of the relevant case data arranged by gender and ordered from High to Moderate according to three broad categories.

Similarly, female participants do not differ significantly from male participants in the characteristics of their final products. However, small qualitative differences between female and male case groups are evident. Slightly stylistic differences can be seen in the spatial layouts created by female participants (Cases 1, 3, 7, 8) when compared to their male counterparts. The female participants showed a tendency to use specific geometric forms to subdivide interior space and to include particular blocks as separated objects within the spatial design. On the other hand, products created by male participants (Cases 2, 4, 5, 6) have more variety in the structural features (i.e., columns, archways, ramps) included in the spatial layout than those created by female participants.

Further analysis of descriptive data reveals that possible developmental differences may exist between female and male participants. The female children ranged in age from 4 years, 10 months to 5 years, 0 months. In contrast, the males range in age from 4 years, 5

Table 10. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Sex Differences)

			Female		
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
High					
	7 1 8	5-0 5-0 4-10	Keen sense of spatial understanding through body orientation; Very planful in sequence and execution of fine and gross motor movements; Seemed to have a definite spatial plan in mind; Sensitive to artistic elements; Seemed to refer to a central theme; Variety of implementation strategies: creates a spatial forms in a many arrangements using the same block forms.	Successful in solving almost problems efficiently and effectively in creative ways; Approximately 10-20 problem types; Unintentional problems related placement of blocks in vertical or unique part of block form; Intentional problems related to negative space or addition of large blocks into the spatial layout; Variety of solution categories: experimentation with geometric forms.	Persistent involvement for almost all of the activity; Variety of responses about structural aspects of constructions; Very cooperative, polite or respectful in interactions with observer; Very confident; preferred to solve problems on Very close attention to detail.

Table 10. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Sex Differences)

			Female		
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
High-Moderate					
	3	4-11	Spatial understanding through body orientation; Planful in the sequence and execution of physical movements; Seemed to have a spatial plan in mind; Some variety in implementation strategies: tactile exploration.	Successful in solving most all of problems in effective ways; More than 15 problem types; Unintentional problems related placement of geometric forms in the spatial design; Intentional problems related to exactness of block alignment in spatial form Consistent use of same solution categories.	Persistent involvement in the process of block construction; Cooperative and responsive to observer; Some verbal responses about the product at the end of the activity; Seemed confident; Attention to detail.

Table 10. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Sex Differences)

			Male		
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
High					
	6 2	5-1 4-9	Spatial understanding through body orientation; Very planful in sequence and execution of physical movements; Seemed to have a spatial plan in mind; Sensitivity to elements found in art and architecture; Seemed to refer to a central theme or spatial concept. Variety of implementation strategies.	Successful in solving almost all of problems efficiently and Less than 15 but not more than 20 problems; Unintentional problems related block placement in vertical or unique arrangements; Intentional problems related to the construction of unique spatial forms; Variety of solution categories: invention of ramp and arches, experimentation.	Persistent involvement for all or most of the activity; Verbal and nonverbal communication with the observer; Cooperative and respectful; Very confident; Prefers to solve problems on own; Close attention to detail.

Table 10. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Sex Differences)

			Male		
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
High-Moderate					
	4	4-10	Spatial understanding through body orientation; Planful in sequence and execution of physical movements; Seemed to have a spatial plan later in the process; Some variety in implementation strategies: study of visual model.	Successful in solving most all problems; More than 30 problems noted; Almost all of the problem types related to the creation of a product based on a visual model; Some variety in solution categories: verbal planning, problem definition.	Persistent involvement; Many verbal requests and interactions with observer related to the process of construction; Cooperative and polite; Attention to detail.
Moderate					
	5	4-5	Spatial understanding through orientation of product; Did not seem to have a to have a spatial plan until second half of the activity; Consistent use of strategies.	Successful in solving half of the problems; More than 30 problems; Unintentional problems related to block placement; Intentional problems related Less variety of solution categories: trial & error.	Persistent involvement in the task; Some verbal responses at end of the activity; Cooperative in interactions with observer; Some attention to detail.

s to 5 years, 1 month. Clearly, Case 5 stands out from all the other participants when chronological age is considered. His age at the time of the assessment was 4 years, 5 months. Therefore, he is approximately 5 to 6 months younger than the three oldest participants, Cases 1, 6, and 7, respectively. Observed behaviors for female and male participants ordered as High-Moderate (HMO) and ordered as Moderate (MO) are found to be less mature than those participants ordered as High (HO). In addition, the block construction created by Participants 3, 4, & 5 can be characterized as more simplistic the overall layout of the spatial forms. Table 11 is a visual display of the composite of the relevant case data arranged by gender and ordered from High to Moderate according to the three broad categories of final product characteristics.

Ability Differences and Case Results

The problem solving behaviors and working styles of the cases ordered as High (HO) are clearly different from the cases ordered as High-Moderate (HMO) and the single case ordered as Moderate (MO). Obvious ability-related differences can be seen when Cases 1, 2, 6, 7, 8 are contrasted with Cases 3, 4, and 5.

Within-case group analysis of those cases ordered as High (Cases 1, 2, 6, 7, & 8) shows more similarities than differences in patterns of behaviors across the three categories. Participants in the HO group show more flexibility in the number and the variety of solution categories noted. A preference to solve problem types on their own volition and in efficient and effective ways is demonstrated. The total number of problems encountered or created is greater than that for the HO participants. In addition, subtle

Table 11. Characteristics of Final Products: Sex Differences

Case Order	Female Case-Ordered Group						
	Case #	Age	Number of Products	Symbols	Spatial Form Description	Key Features	Process of Development
High	1	5 - 0	1 Spatial Form	"A Castle."	Enclosure (erect) with subdivided interior space and one separated object	Incorporated all blocks Elaborate detail Varied dimension Very complicated spatial layout	Complex 6 stages Many modifications One major transformation
High to Moderate	7	5 - 0	2 Spatial Forms	House (Product 1 & 2) "bedrooms, kitchen, flower house, restroom," "door, stairs, slide, swing, rock"	Enclosure (combination) with subdivided interior space: separated and attached objects	Incorporated 23 to all blocks Varied design Very complicated spatial layout Detailed Other: attached covered enclosure; recurring geometric pattern in spatial design	Simple: 2 stage (Product 1) Complex; 4stages (Product 2) Several modifications Several transformations
	8	4-10	1 Spatial Form	"A Horsie."	Enclosure (erect) with interior space	Incorporate all blocks Complicated spatial layout Varied dimension Triangular shaped Detailed	Complex 4 stages Several modifications 2 major transformations
Moderate	3	4-11	1 Spatial Form	"A house." A house with specific blocks representing animals.	Enclosure (flat) with interior space subdivided (Product 1) Enclosure (flat) with several separated objects in interior space.	Incorporated 14 - 24 blocks Uniform geometric design Some detail	Simplistic 2 - 4 stages

Table 11. Characteristics of Final Products: Sex Differences (continued)

	Male Case-Ordered Group						
Case Order	Case #	Age	Number of Products	Symbols	Spatial Form Description	Key Features	Process of Development
High	6	5-1	1 Spatial Forms	A house.	Enclosure (erect) with interior space	Incorporated all blocks Very complicated spatial layout Varied design Other: Attached a variety of arches.	Complex 8 stages Many modifications One major transformation
High to Moderate	2	4-9	2 Spatial Forms	"A horse corral." (Product 1) "A horse corral and a house." (Product 2) A house	Enclosure (erect) with interior space Enclosure (combination) with covered interior space	Incorporated 33 - all blocks Complicated spatial layout Varied design Other: Invented a working ramp.	Simplistic 1 stage; 5 stages Many modifications Several transformation
Moderate	4	4-10	3 Spatial Forms	A house (Products 1 & 2) A house with a roof (Product 3)	Stack Row (combination) Enclosure (combination) with covered interior space	Incorporated 4 - 25 blocks Variety of spatial designs Other: Used illustration on box as visual model (Product 3)	Simplistic 1 - 4 stages Several modifications One major transformation
	5	4-5	5 Spatial Forms	Unknown (Products 1 & 2) A House. "My Mom and Dad's house." (Products 3 - 5)	Stack Pile (combination) with two separated objects (exterior)	Incorporated 5 - 15 blocks Varied spatial design	Simplistic 1 - 5 stages Many modifications Several major transformations

differences were found in the working styles of case participants ordered as High. The level of persistent involvement in the activity coupled with greater self-confidence and focused attention to detail provides evidence of a high degree of goal-directed behavior.

The most striking difference found between the HO participants and those not ordered as High was the eye tracking patterns and visual-spatial analysis behaviors noted. HO participants were quick and systematic in their analysis of the block construction before searching for a targeted block or alternative solution response whereas the participants not ordered as High frequently searched back and forth and back and forth between the block construction and the block solution alternative. Table 12 is a next-step version of the relevant descriptive data comparing the observed behaviors between the HO participants and the non-HO participants.

Cultural Differences and Case Results

Clear differences between Hispanic-Urban and Navajo-rural case groups are evident in the observed spatial behaviors and the evaluation of spatial aspects of the final products. Evidence of cultural differences in the spatial area between Hispanic and Navajo participants are found, favoring the Navajo children. Table 13 is a visual display of the composite of the relevant case data arranged by culture and ordered from High to Moderate according to the three broad categories of observed behaviors.

Initial cross-case analysis of the descriptive data arrayed reveals obvious differences in spatial abilities. All four Navajo participants (Cases 2, 6, 7, 8) are shown to be in the High-ordered case group, whereas only one Hispanic case (Case 1) is included in the High

Table 12. Differences in Patterns of Behaviors Observed Between Case-Ordered Groups

High Ordered	**High to Moderate Ordered**
Problem Solving	Problem Solving
Less frequent number of problems encountered or created	More frequent number of problems encountered or created
Flexible use of solution strategies	Less flexible in solution strategies
Preference to solve problems on own in more efficient and effective ways	Solved majority of problems in effective ways
Quick and systematic visual-spatial analysis of construction before search for block solution alternative	More repetitive (back and forth) search for the block solution alternative
Working Style	Working Style
Appeared very confident	Appeared confident, overall
Highly goal-directed	Goal-directed
Attention to finer detail in the spatial layout	Attention to detail (in general) of spatial layout

Table 13. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Cultural Differences)

	Hispanic				
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
High	1	5-0	Keen sense of spatial of spatial understanding through body orientation; Very planful in sequence and execution of physical movements. Seemed to have a definite spatial and verbal plan; Seemed to refer to a central theme or central concepts of dimension and symmetry; Sensitivity to artistic elements and architectural elements. Variety of implementation strategies: used chest as a prop and foot as a tool.	Confident in solving all unintentional problems on own; Less than 15 problems encountered; Unintentional problems related to placement of blocks in vertical arrangements; No intentional problems created; Variety of solution categories; problem definition to self, verbal planning, and experimentation with a variety of geometric forms;	Very persistent; Variety of imaginative verbalizations verbalized about product; Highly creative block play ; Very cooperative; verbally responsive with observer.
High Moderate	4 3	4-10 4-11	Spatial understanding through body orientation; Spatial understanding through planful in the sequence and execution of physical movements; Seemed to have a spatial plan at some point during the process of product development; Some variety of implementation; body repositioning, body reorientation.	Between 15-30 problems noted; Successful in solving the majority of problems; Unintentional problems related to the implementation of the spatial plan; Intentional problems related to placement or alignment of blocks in the spatial design;	Persistent involvement; Cooperative and polite in interactions with observer; Creative or block play (in general); Some verbalizations made about a

Table 13. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Cultural Differences)

	Hispanic				
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
				Variety of Solution Categories: invention of functional or unique structures; experimentation with dimensions of unique block constructions and geometric forms.	problem or product; Some attention to detail.
Moderate					
	5	4-5	Sense of spatial understanding through orientation of product; Did not seem to have a spatial plan until much later in the product development process; play with blocks; Less variety of Implementation Strategies; constructed similar versions of the same basic form of the same basic form.	More than 30 problems types; Successful in solving more than half of the problems; Unintentional problems related to block placement in vertical arrangements; Intentional problems related to the addition of dissimilar geometric forms; Less variety of solution categories; trial and error and some experimentation.	Persistent involvement; Quiet and cooperative.

Table 13. Understanding Spatial Intelligence Through Problem Solving: Behaviors Observed (Cultural Differences) (continued)

			Navajo		
Case Order	Case #	Age	Spatial Abilities	Problem Solving	Working Style
High					
	6	5-1	High spatial understanding through orientation of body and product; very planful in the sequence of execution of physical movements which were well coordinated; Keen observer of spatial forms and other persons in and around the work area; Seemed to have a definite spatial plan in mind; seemed to refer to a central theme and spatial concepts of dimension and asymmetry; Sensitivity to elements found in art and architecture. Variety of implementation strategies: rebuilds/starts over the development of unique structural forms (i.e., ramps, arches); creative experimentation.	Confident in solving a majority of intentional and unintentional problems on own; Less than 10-20 encountered or created; Unintentional problems related to placement of blocks in a vertical or unique arrangement and incorporation of particular block forms or block arrangements into the spatial layout; Intentional problems related to negative space and the development of unique spatial forms. Variety of solution categories: created ramps and arches, creative experimentation.	Persistent to very persistent involvement; Highly inventive and creative in block play; Very cooperative, respectful in interactions with observer Some verbalizations about the product at end of activity; close attention to detail of parts within the whole spatial form.
	7	5-0			
	8	4-10			
	2	4-9			

ed group. In contrast, three of the four Hispanic participants are ordered as either High-Moderate (Cases 3 & 4) or Moderate (Case 5).

For the purpose of this analysis, the researcher excluded Cases 1 and 5, in an effort to rule out ability-related differences and developmental-related differences. Further analysis of the data arrayed shows that the Navajo children exhibited several distinct spatial patterns of behavior. First, the Navajo children engaged more often in experimentation with spatial relationships while building with blocks. In fact, each of the Navajo children seemed to be referring to central concepts of dimension and asymmetry as they executed their spatial plan. On the other hand, the Hispanic participants often engaged in verbal planning while the Navajo participants tended to solve problems most often in purely spatial ways. Table 14 is a the next-step version of the relevant descriptive data comparing the observed spatial behaviors between the Navajo participants and the Hispanic participants.

Comparable results are found in characteristics of final products created by Navajo participants. Initial cross-case analysis of the descriptive data arrayed reveals clear differences in final product characteristics across the three broad categories. Table 15 is a visual display of the composite of the relevant case data arranged by culture and ordered from High to Moderate. The spatial forms created by Navajo participants can be characterized as large, three-dimensional, asymmetrical block constructions. Other product features included geometric patterns and structural features found in art and architecture. The final products created by the Navajo children can be characterized as

Table 14. Differences in Patterns of Behaviors Observed Between Cultural Groups

Navajo	Hispanic
Spatial Behaviors	Spatial Behaviors
Spatial abilities ordered as High	Spatial abilities ordered as High to Moderate
Seemed to refer to central concept of varied dimension, balance, and asymmetry	Seemed to refer to central concept of dimension and balance
Seemed to have a definite spatial plan in mind at the start of the activity	Seemed to have verbal/spatial plan in mind during the activity
More variety in implementation strategies	Less variety in implementation strategies

Table 15. Characteristics of Final Products: Cultural Differences

			Hispanic		
Case Order	Case #	Age	Spatial Form Description	Key Features	Process of Development
High	1	5-0	Enclosure (erect) with subdivided interior space	Incorporated all blocks Varied structural design Complicated spatial layout Many artistic elements	Very complex More than 5 stages Many modifications to parts of whole One major transformation
High to Moderate	4	4-10	Stack Row (combination) Enclosure (combination)	Incorporated at least half of blocks Varied spatial design (some detail) Some artistic elements	Simplistic 1-4 stages Several modifications to parts of whole One major transformation
	3	4-11	Enclosure (flat) with subdivided space Enclosure (flat) with attached objects in interior space	Incorporated at least half of blocks Uniform spatial design Some artistic elements	Simplistic 2-4 stages Many modifications to parts of whole One major transformation
Moderate	5	4-5	Stack Pile combination Pile combination with separated objects	Incorporated less than half of blocks Some artistic elements	Simplistic 1-5 stages Many modifications to parts Several major transformations

Table 15. Characteristics of Final Products: Cultural Differences (continued)

Case Order	Navajo Case #	Age	Spatial Form Forms	Key Features	Process of Development
High					
	6	5-1	Enclosure (erect) with interior space	Incorporated all blocks Varied design (elaborate) Complicated spatial layout Many artistic and architectural Elements	Very complex More than 5 stages Many modifications to parts of whole One major transformation
	7	5-0	Enclosure (flat) with interior space Enclosure (combination) with subdivided interior space, separated objects, and attached objects	Incorporated almost all blocks Varied design combination Elaborate spatial layout	Varied complexity 2-4 stages Several modifications to parts of whole Several major transformations
	8	4-10	Enclosure (erect) with interior space	Incorporated all blocks Varied design (detailed) Elaborate spacial layout Many artistic elements	Varied complexity Four stages to parts of whole Two major transformations
	2	4-9	Enclosure (erect) with interior space Enclosure (flat) with interior space (incomplete)	Incorporated almost all blocks varied design Complicated spatial layout	Varied complexity 1-5 stages Many modifications to parts of the whole. Several major transformations

lex spatial forms that more closely resembled the visual-spatial likeness of real-life physical structures or objects (Cases 6, 7, 2). The product created by Participant 8 did not necessarily resemble the form of a horse; however, some spatial features of her final product that look like the real-life features of a horse such as the mane, head, and tail. The block constructions created by the Navajo children are more sophisticated and elaborate whereas those created by the Hispanic Participants show less complexity and appear rudimentary by comparison. Thus, the block constructions produced appear to be distinct in terms of a variety of spatial forms found within the traditional Navajo culture. Table 16 is a next-step version of the relevant descriptive data comparing the spatial features characterizing the final products between the Navajo participants and the Hispanic participants.

Individual Differences and Case Results

To better understand cultural differences between individuals with high potential in the spatial area, the researcher completed one final analysis. The behaviors observed and product descriptions of the two most exemplary cases within the High ordered group, Cases 1 and 6, respectively, were compared and contrasted to determine qualitative differences in patterns of observed behaviors and in the descriptions of final products. Significant differences in behaviors observed and characteristics of final products were not found between the Hispanic female child and the Navajo male child..

Although these two cases are comparable across all descriptive categories of the data displays, further analysis of categorical data for behaviors observed showed subtle

Table 16. Differences in Spatial Characteristics of Final Products Between Cultural Groups

Navajo	Hispanic
Spatial Features	Spatial Features
All blocks combined in many ways to produce complex three-dimensional forms	Most blocks combined in similar ways to produce basic two-dimensional (combined) forms
Complex spatial layout with elements found in art and architecture	Less complicated spatial layout with some elements found in art or architecture
Asymmetrical appearance (generally)	Symmetrical appearance (generally)
More closely resembled the visual likeness of the physical structure	Some resemblance to the visual likeness of the physical structure

differences. In fact, Case 1 stands out from all of the cases ordered as High. First, Case 1 did not create any intentional problems during the assessment activity. Secondly, a minor difference was noted in the number and variety of spontaneous comments she made to the observer. These differences, though small, are likely nuances of behavior that may be unique to the individual's communication style. Thus, no clear differences were found between the behaviors observed and final products created by these two children with apparently unique spatial cognitive profiles.

Research Question 4

How are these behaviors and products similar to the core capacities of spatial intelligence?

Gardner presented a broad definition of the fundamental aspects of spatial thinking. Although he described four key components of the capacities involved in the spatial domain, he did not establish specific behaviors that can be observed in the problem solving of individuals across a range of ages. Furthermore, he did not establish clear characteristics of products created by individuals. Therefore, the core capacities of spatial intelligence are vague and require further exploration and expansion. To address this concern, the researcher posed the fourth and final research question. Cross-case construct tables were used to cluster descriptive data according to the four capacities across the eight cases. As shown in Table 17, general statements of evidence of the core capacities and specific examples of like spatial capabilities exhibited by the participants are presented.

Table 17. Spatial Intelligence: Case Evidence for Gardner's Core Capacities

Core Capacity 1:	Core Capacity 2:	Core Capacity 3:	Core Capacity 4:
The ability to recognize instances of the same element.	The ability to transform or to recognize a transformation of one element into another.	The ability to conjure up mental imagery and then transform that imagery.	The capacity to produce a visual likeness of spatial information.
Statement - This ability was evident in the performance of the following participants: Cases 1, 2, 3, 4, 5, 6, 7, 8.	**Statement** - This ability was demonstrated by the following participants: Cases 1, 2, 3, 4, 6, 7, 8.	**Statement** - This ability was evident in the verbalizations of the following participants: Cases 1, 3, 7.	**Statement** - This capacity was evident in the spatial representations of the following participants: Cases 1, 2, 3, 4, 6, 7.
Examples - Case 1: She added the same elements (i.e., 3 block columns with a triangle block on top of the stack) to the sides of her block construction to create matching tower-like structures. Case 2: He added the same elements (i.e., 3 small square blocks, 3 large square blocks) to create the front and right sides of his second product (i.e., corral). Case 3: She added the same elements (i.e., 3 round column blocks) to subdivide the interior space of the enclosure (Product 1). These blocks were removed and added to the front side of the enclosure (Product 2) to create matching vertical columns. Case 4: He demonstrated	**Examples** - Case 1: She constructed two separated versions of her original pair of towers (attached objects) which varied in size and block composition. Then, she added them to the front side of her construction representing "a castle". Case 2: He constructed three different openings to his enclosure representing "a corral" which varied in location and block composition. Case 3: She constructed her second product (i.e., a square shaped house) from a different orientation (i.e., attached to bookshelf) than the first product (i.e., rectangle shaped house), transforming the size and shape of	**Examples** - Case 1: At the start of the activity, she indicated to the observer exactly what she intended to build. She stated: "Let's make a castle". [Held up the triangle block to show the observer.] Case 3: She made three statements to the observer about her second product. "I doing it. Making it. I'm making it because I'm going to put something in it." [Looks up. Makes eye contact with the observer.] "Um...things that goes to the house." After completing the block construction, she stated: " Look it. It is houses with cows in it...and cats and fishes...in the water." Case 7 - She readily labeled key structural features and pointed out	**Examples** - Case 1: Her final product resembled a model of a castle having 3 prominent towers and a strong facade. Case 2: As part of the development of the first product, he created a working structure which resembled a ramp found on a highway. Case 3: Her first product resembled a simple blueprint of a four room building. Case 4: In the second stage of his third product, he created a two-dimensional construction that resembled a graphic depiction of a young child's drawing of a three-sided house with a two-sided pointed roof on top. Case 6: During the stages of

Table 17. Spatial Intelligence: Case Evidence for Gardner's Core Capacities (continued)

Core Capacity 1:	Core Capacity 2:	Core Capacity 3:	Core Capacity 4:
persistence in building a replica of the house pictured in the diagram located on the side of the box. Case 5: He created five products. Each product was a similar version of the same basic spatial form of a stack or combination of stacks on a wide base. Case 6: He combined two large rectangle blocks in a row to create the base of his construction. Then, he added two triangle blocks in a row. Between the triangle blocks, he placed two square column blocks in a stack. Case 7: She recognized, found, and placed the same elements (i.e., small, square blocks) in a row and spaced them equidistant from the other in the interior space of her enclosure (Product 1). Case 8: She arranged two square blocks in a row (i.e., same length as one large rectangle block). Then, she placed two large rectangle blocks to create a three-sided enclosure (i.e., a horse).	the spatial form. Case 4: Twice he transformed his 2-D enclosure of a house. The first time, he transformed the five sided enclosure into a smaller version of the original geometric form. The second time, he transformed it into a 3-D covered enclosure to create a house with a roof. Case 6: He compared many block forms and then combined two blocks to create one spatial form, transforming its shape and size (1 wedge block + 1 wedge block = 1 large rectangle block form). Case 7: She added a 2-D row composed of 4 same size blocks to the second product (house). Then, she transformed it into a 3-D covered cube with one open side (i.e., one of two bedrooms). Case 8: She constructed a 2-D enclosure (i.e., triangle form). Then, she transformed it into a larger, 3-D enclosure having the same geometric design.	to the observer their respective locations in her second product.	product development, he created a variety of 3-D attached structures that resembled archways in a building. Case 7: She created a spatial diagram which resembled a blueprint of a house with six rooms (i.e., 2 bedrooms, 1 kitchen, 1 restroom, and many structure features (i.e., 3 sets of stairs, 1 slide, 1 passageway, and 1 door). She created several separated objects to finish interior and exterior of the "house" (i.e., 2 beds, 1 rock, and 1 swing).

Ability to Recognize Instances of the Same Element

This ability was evident in a sensitivity to geometric/visual forms and a sensitivity to spatial composition. The ability to perceive a spatial form or object was evident in the behaviors observed and in the final products of the eight participants. This ability was evident in the performance of all participants (Cases 1, 2, 3, 4, 5, 6, 7, 8). Each of the participants showed sensitivity to geometric forms in block selection, block combinations, and blocks arranged in the spatial design of their products. In addition, those Cases ordered as High (Cases 1, 2, 6, 7, 8) showed a sensitivity to nuances of finer detail in the physical world and symbolically represented as key features (i.e., castle columns, ramp, archways, bedroom) of the block constructions. Case 7 stands out from the other cases because she created the greatest number and variety of structural features (i.e., 4 separate rooms, 2 separate beds, 3 sets of stairs, 1 door, 1 slide) as part of the spatial representation of a house.

Ability to Transform or to Recognize a Transformation of One Element into Another

All but one of the eight participants demonstrated this capacity (Cases 1, 2, 3, 4, 6, 7, 8). This ability was evident in particular in an appreciation of spatial forms manipulated in space as experienced through the sense of touch, as viewed from different angles, and as experienced through exploration in block play. One clear example of this ability was demonstrated by Case 6. He experimented with the positioning of two right wedge blocks and combined them to make a rectangular block form. Then he held a whole square block and rotated it horizontally over the top of the previous block combination to match the shape before placement.

Ability to Conjure Up Mental Imagery

According to Gardner the ability to create a "picture in the head" relies on an acute visual memory and often is couched in verbal form. The case descriptions did not include participant interviews about the awareness of mental images for spatial plans they perceived. However, two of the eight participants, Cases 1 and 7, did demonstrate this ability in verbal form. The modifications and transformations participants made during the process of product development may be indications of visual-spatial thinking with mental images. Furthermore, the frequent eye and head movements, eye tracking, and quick, systematic analysis of the product before searching for a block may be suggestive of this capacity. Cases 1, 2, 6, 7, and 8 in particular exhibited these behaviors throughout the problem solution process as noted in the case descriptions.

Capacity to Produce a Graphic Likeness of Spatial Information

Many of the case descriptions of final products provided evidence of the recreating their visual world through block construction. Evidence of this capability can be found in the examples for Case 1, 2, 3, 4, 6, 7. More specifically, this capacity was evident in an ability to manipulate the blocks presented to create two-dimensional and 3-dimensional spatial forms having similar visual likeness of spatial information found in a castle (Case 1), a corral with working ramp (Case 2), a house with several rooms (Case 3), a house with a roof (Case 4), a house with archways (Case 6), and a house with four rooms and many structural features (Case 7). Case 7 in particular stands out from the case study descriptions of characteristics of final products. Based on verbal responses to the observer, her final product (Figure 7) showed a detailed floor plan or diagram of a house which seemed to be familiar to her. Not only did she identify definite areas of separated space as specific rooms, such as the two separate bedrooms and the restroom, she created three-dimensional structural features such as a passageway (arch), a bedroom (covered enclosure) and a slide (large rectangle block angled against the covered enclosure) as part of the elaborate spatial layout of "a house". In addition, six of the eight participants (Cases 1, 2, 6, 7, & 8) created products in which the spatial layout of the form varied in detail, dimension, symmetry, and the number of separated or attached structural features. Case 1 and Case 6 had the most notable spatial representations. Participant 1 (Case 1) symbolically represented a "castle" that was elaborate and very complex. Similarly, Participant 6 (Case 6) constructed a "house" with many arches and a ramp as part of the complex spatial layout. They used realistic features and deliberately chose blocks and spatial patterns to produce very different products. The block construction created by Participant 1 could be characterized as an artistic representation of an imagined dwelling or medieval, European castle, whereas Participant 6 created a real-life version of a home composed of several features of architecture. Thus, these examples of products created by two five year olds having distinct individual profiles in the spatial area-provide evidence of a what Gardner refers to as " a sensitivity to the various lines of force".

Learning style is the typical way young children acquire knowledge, skills and understanding of their concrete, physical world. The construct comparison Table shows that spatial observational learning and thinking was evident in the behaviors observed and the products by participants across the core capacities of spatial intelligence as described by Howard Gardner. Furthermore, common patterns of spatial abilities and interests were noted that characterize the spatial profiles of individual participants who share a common cultural, linguistic, and socio-economic background. The case descriptions demonstrate the existence of the core capacities of intelligence in varying degrees among the eight participants, who ranged in age from 4 years, 5 months to 5 years, 1 month. Case 1 stands out from all of the case studies because evidence was found across each of the four capacities.

Summary

In response to Question 1, three broad categories of observed behaviors were delineated. They included patterns of behaviors, specifically the following: Spatial, Problem Solving, and Working Style. In response to Question 2, three broad categories of characteristics of final products were delineated. These categories included the following: Spatial Form Description, Key Features, and Process of Development. The three descriptive categories for observed behaviors and the three categories for characteristics of final products were the basis of the eight single case study reports.

In response t Question 3, sex-related differences were not found in the behaviors observed and characteristics of products between females and males. In contrast, strong cultural differences in behaviors and products were found overall between the Hispanic and Navajo case groups across all descriptive categories. Clearly, the spatial behaviors, problem solving behaviors, and working styles of the Navajo children participating in the study were superior to their Hispanic counterparts. Similarly, the Navajo children's final products can be characterized as more sophisticated in the overall spatial layout. Furthermore, the children's spatial representations more closely resembled the visual likeness of spatial representations found in the physical world.

Examination of the behaviors observed and the characteristics of products for similarities across Gardner's core capacities of spatial intelligence (Question 4), showed that overall the young children in this study demonstrated evidence of the four capabilities. Specific case examples of core capacities in the spatial domain were noted. Clearly, the ability to recognize instances of the same element was found in each of the eight participants. The ability to transform or recognize a transformation of one element into another was found in all but one of the eight participants. The capacity to produce a visual likeness of spatial information was found among all but two of the eight participants. Less clear, however, was the capacity to conjure up mental imagery and then transform that imagery.

CHAPTER 5

DISCUSSION

This is a study of spatial problem solving abilities and spatial features of products created by young children from different cultural, linguistic, and geographical backgrounds prior to an intervention program. The findings of this study were presented in Chapter 4 and organized according to the research questions delineated in Chapter 1. A summary of the findings will be discussed below, followed by a summary of the design, a general discussion of the results, implications for the field of the education of the gifted, and suggestions for future research.

Summary of Design

The primary purpose of the study was to describe in detail the spatial and problem solving behaviors that could be observed and the spatial characteristics of the products created by young Hispanic children and young Navajo children on the spatial activity of the DISCOVER IV performance-based assessment. A secondary purpose of the study was to determine if careful observation of the behaviors exhibited by participants, combined with an evaluation of final products constructed, could clarify and extend the understanding of the core capacities of spatial intelligence as described by Howard Gardner.

The eight participants in this study were videotaped in a bilingual enrichment classroom as they engaged in solving an open-ended block construction task on the

DISCOVER IV assessment. Case study, task analysis methods (Moon, 1991) were employed as way to (a) provide detailed, intensive descriptions of the spatial problem solving behaviors and products created by the children videotaped during the assessment process; (b) determine the existence of differences and spatial abilities between case groupings formed on the basis of gender and culture; and (c) provide an understanding of competence in the spatial area of intelligence as an important component of ability in the problem solving of young male and female children from diverse backgrounds with potential gifts and talents.

The study was an embedded, multiple case study design (Yin, 1994). Two units of data analysis were incorporated to respond to the four research questions posed in this study and to enhance the researcher's insight about each of the single case studies and the cross-case contrasts/comparisons. In the larger unit of analysis, the researcher focused on the detection of individual and case group differences in the in-depth profiles of participants. One subunit of analysis involved the detection of sex-related differences and ability-related differences in the spatial behaviors, problem solving, and spatial characteristics of final products created by participants in the Female case group and those in the Male case group. Another subunit of analysis involved the detection of culture-related differences in the spatial behaviors, problem solving, and spatial characteristics of final products created by participants in the Hispanic-Urban case group and those in the Navajo-Rural case group.

Eight single-case studies were conducted following a replication logic approach. This approach must be distinguished from the sampling logic approach to inquiry used by the researchers in the studies criticized in the previous review of relevant literature discussed in Chapter 2. Robert Yin, in his book, *Case Study Research: Design and Methods*, explains that multiple cases should be considered as multiple experiments not as multiple respondents in a survey or multiple participants within an experiment. According to Yin (1994), the application of sampling logic to case study research is a mistaken analogy. Furthermore, he contends that the criteria for determining sample size also is irrelevant in multiple case study design. In his view, it is better for the researcher to (a) think of the number of cases "as a reflection of the number of case replications (both literal and theoretical)" that she would like to have in her study; and (b) recognize the number of replications the researcher wants to have "depends on the upon the certainty" she wants to have about the multiple case results. Thus, in the present study, eight case replications were conducted to obtain a higher degree of certainty.

Data were analyzed systematically using the data collection and single case study analysis procedures developed and tried during the pilot study. First, in an effort to address Questions 1 & 2, the researcher used an report analysis procedure to describe and explore patterns within the Hispanic-Rural case group and within the Navajo-Rural case group. Second, in an effort to address Question 3, the researcher used descriptive case-oriented strategies to analyze and synthesize multiple cases in clusters that share certain patterns. Master charts or "meta-matrices" were designed to better understand differences among individual cases and cross-case groups (Miles & Huberman, 1994). First level descriptive data from each of the eight case reports were assembled in a partially-ordered display by two variables: gender and culture. Next, case-ordered descriptive matrices were designed to assemble relevant data from each case report to make cross-case contrasts/comparisons. A set of rating criteria was established to order the cases so that differences could be seen easily among High, High-Moderate, and Moderate cases (see Chapter 4). More specifically, the female and male case-ordered displays contained data arrayed case by case according to variables of interest across the broad categories of observed behaviors and the broad categories of characteristics of final products. The researcher looked down each of the columns of the categories established for behaviors observed (Sex Differences) to find distinct patterns characterizing high spatial problem solving abilities. These categories included the following: Implementation Strategies, Problem Types and Solutions, Unrelated Behaviors and Expression of Emotion, and Summary Statements. Using the set of criteria, the researcher sorted each case on key dimensions of spatial abilities and problem solving strategies. Patterns of spatial problem solving behaviors were analyzed before ordering the cases. Subsequently, each case was ordered as High, High-Moderate, or Moderate based on how key variables and processes worked. Likewise, the researcher looked down each of the columns of the categories established for final product characteristics (Sex Differences) to to find distinct patterns characterizing the particular spatial aspects of block constructions produced. These categories included the following: Number of Products created, Symbols for Spatial Representations, Spatial Descriptions, Key Features, Process of Product Development, and Total Time Involved in Task. Once again, the researcher sorted cases within the Hispanic-Urban case group and those within the Navajo-Rural case group using the same procedures stated above to determine patterns of culture-related differences. Next, distinct patterns of spatial behaviors, solution strategies, and spatial characteristics of products between High to Moderate cross-case groups were reduced, arranged according to noteworthy categories, and displayed in next-step versions of the initial case-ordered matrix for observed behaviors and the initial matrix for final product characteristics. To better understand differences between male and female case groups, the researcher contrasted the case descriptions of high and moderate exemplary cases. The same steps were followed for the analysis of descriptive data arrayed and ordered in the matrices and next-step version tables for the cross-case contrasts/comparisons between the Hispanic-Urban cases and the Navajo-Rural cases. Finally, in an effort to address Question 4, a cross-case construct matrix was developed to cluster descriptive case report data according to Gardner's core capacities based on similarities across the eight cases.

General Discussion of Results

A paucity of research exists in the area of spatial thinking and young children. A small yet contradictory body of literature about the processes of problem solving in young children with gifts and talents exists as well. However, until recently little attention has been given to the examination of the cognitive dimensions of young children's problem solving in the spatial area of the intelligence. Robust case descriptions of how young children from diverse backgrounds are thinking in spatial ways through problem solving on the block construction task of the DISCOVER IV pre-kindergarten assessment were provided in the present study. The discussion that follows revolves around developmental differences noted among the eight participants and the possible effect of this variable on the multiple case study results.

Variability in the spatial and problem solving abilities identified across the eight participants, who ranged in age from 4 years, 5 months to 5 years, 1 month, were noted. Clearly, developmental factors must interact to explain the variability in the observed behaviors and characteristics across these individual children. This factor was particularly evident given the six month age difference between the youngest male participant (Case 5) and the oldest male participant (Case 6). Individual case profiles of the participants problems solving strengths and interests in the spatial area of intelligence also show evidence of varied strengths in other domains of the intelligence, specifically the linguistic, bodily-kinesthetic, interpersonal, and intrapersonal areas. Furthermore, some variability was found as noted in the working styles of the participants. Small subtle differences were found in the degree of attention to detail in the spatial layout of block constructions produced by the youngest and oldest children in the study. Thus, these findings are consistent with the Project Spectrum research results (Krechevsky & Gardner, 1994).

Qualitative differences in the spatial and problem solving abilities of male and female children were undetectable. The sex-related differences in the spatial abilities of young children in this study were found to be consistent with previous studies (Boardman, 1990; Etaugh & Levy, 1981; Johnson & Mead, 1987; Linn & Petersen, 1985, Maccoby &

Jacklin, 1974; McGee, 1979). Similarly, female participants did not differ significantly from male participants in the spatial characteristics of their final products. However, further analysis of case descriptive data revealed that developmental differences may have confounded the comparisons between the female and male participants. The female children in the study ranged in age from 4 years, 10 months to 5 years, 0 months. In contrast, the male children in the study ranged in age from 4 years, 5 months to 5 years, 1 month. The significant age differences across the male and female cases provide evidence of varied patterns of development in the "stream" or domain of spatial intelligence. Case 5 (Hispanic-Urban, male) stands out from all of the participants in the study when chronological age is considered. Essentially, he is 5 to 6 months younger than the three oldest participants, Cases 1, 6, and 7, respectively. He was the only participant to be ordered consistently as Moderate or as having the lowest order across all broad categories of observed behaviors and all of those delineated for final product characteristics. Analysis of his behaviors when compared to his male, female, or cultural counterparts he was less mature, overall. Moreover, the five block constructions he created were characterized as the most rudimentary of all the participants in terms of the layout and detail of the spatial forms. In fact, when compared to the other seven case study participants, his case descriptive report findings were negatively skewed. Specifically, this participant (a) did not appear to have a spatial plan in mind until the end of the activity; (b) used the same implementation strategies consistently throughout the activity; (c) encountered or created the most problems (more than 30 problem types noted); (d) was least likely to solve the majority of the block construction problems efficiently and effectively; and (e) was observed to use the highest number of back and forth searches for a block solution alternative before arriving at what he wanted to do in the execution of the spatial plan . Similarly, the quality of the spatial forms he produced were inferior when compared to those of the older male and female participants. More specifically, he created the most spatial forms of all the participants, but they were variations of the same basic design (block pile) as spatial representations of a "house". He incorporated the least number of blocks in the spatial layout (less than 16 geometric forms). Finally, he made the most modifications to rudimentary forms created in 5 or less stages of product development. Using Gardner's conceptualization of waves of early symbolization from the Project Zero research as a basis for comparison, the behaviors observed and the evaluation of the final products created by Case 5, however, may be suggestive of the symbolic capacity of "digital mapping". The total of five forms produced could be an indication of his ability to count numerical groups of objects, his appreciation of symbols for spatial relations of the same kind of object, and his apparent deliberate quantification of the same basic spatial form. Thus, the observed behaviors and spatial appearance of his five block constructions representing a "house" probably were developmentally appropriate for a child who was nearly 4 ½ years of age.

Another salient finding was related to difference in the eye patterns and solution strategies used by participants who were characterized as highly able problem solvers in the spatial task. The eye tracking patterns, quick scanning, and visual-spatial analysis found in the participants ordered as having High abilities in the spatial area may be directly related to the superior block constructing ability evident in the layout of their spatial representations. The high ability participants (a) seemed to be more confident, persistent, and successful in solving spatial problems using flexible solution strategies; (b) showed a preference to solve problems on their own; (c) seemed to be more attentive to detail; and (d) seemed to learn about spatial relationships through experimentation and errors in block constructing. These findings support those of Kanevsky (1990). Thus, the problem solving behaviors and working styles of the cases ordered as high (Cases 1, 2, 6, 7, 8) were superior when compared to those not ordered as High (Cases, 2, 3, 5). Once again, however, the developmental factor may influence the interpretation of these findings of ability-related differences. Three of the five cases ordered as High were five years of age. The striking difference noted in the eye tracking patterns and visual-spatial analysis solution strategies found to be used by the cases characterized as highly capable problem solvers were likely related to developmental differences rather than true individual differences.

One of the most salient findings of this study was evidence of cultural differences between young Navajo-Rural and young Hispanic-Urban participants in the spatial problem solving behaviors and in the ways that spatial representations can be characterized. All four of the Navajo children exhibited definite strengths in the spatial area. Similarly, the quality of the final products created by each of the children was far more sophisticated in terms of specific spatial aspects of dimension, spatial layout complexity, and resemblance to the visual-spatial structures found in the physical world. The researcher concluded that the spatial problem solving abilities of young Navajo children may be more well developed at an early age than those of Hispanic children. Results are consistent with previous studies showing that (suggesting a solidly spatial American Indian test performance pattern) students exhibit spatial strengths (McShane & Plas, 1982).

Once again, developmental differences may cloud the interpretation of these findings. This time, however, the researcher excluded Case 1 (Hispanic-Urban, female, age 5 years old) and Case 5 (Hispanic-Urban, male age 4 years, 5 months old) to rule out factors related to patterns of individual ability and development. Thus, the two Hispanic participants (Case 3: 4 years, 11 months; Case 4: 4 years, 10 months) were much closer in age to the Navajo participants (Cases 2, 6, 7, 8), who ranged in age from 4 years, 9 months to 5 years, 1 months. Analysis of the data arrayed provided strong evidence of several distinct spatial patterns of behavior demonstrated by the Navajo-Rural participants. Specifically, the Navajo participants: (a) engaged more often in experimentation with spatial relationships while building with blocks; (b) seemed to be referring to central concepts of varied dimension, balance, and asymmetry when executing the spatial plan; (c) seemed to have a definite spatial plan in mind at the start of the activity; and (d) tended to solve block construction problems in spatial rather than linguistic ways. Comparable results were found concerning the analysis of descriptive patterns for the spatial characteristics of products created by the Navajo-Rural participants. The spatial representations of the Navajo children were characterized as (a) having much larger, more asymmetrical appearance; (b) comprising of all the blocks combined in many ways to produce more complex spatial forms with varied dimension; (c) containing more geometric patterns found in art and more structural features found in architecture; and (d) resembling the physical structure or object. On the contrary, the Hispanic-Urban participants (a) more often engaged in verbal mediation while building with blocks; (b) seemed to refer to central concepts of uniform dimension and balance; (c) seemed to have a verbal and spatial plan in mind during the activity; and (d) tended to solve block construction problems in both verbal and spatial manners. The spatial feature of the final products created by the Hispanic children, however, were characterized as (a) having a smaller, symmetrical appearance; (b) comprising the majority of the blocks combined in similar ways to produce less complex spatial forms; (c) containing some geometric patterns found in art and architecture; and (d) having some resemblance overall to the visual likeness of the physical structure.

Finally, the results of this study provide evidence that the core capacities of spatial intelligence were evident in the case descriptions of observed behaviors and the evaluation of block constructions produced by 4 and 5 year old children from diverse cultural, linguistic, and geographic backgrounds. All four capacities were noted in at least one of the case descriptions. These findings lend support to Gardner's contention that the spatial area of the intelligence exists in various degrees across individuals. Further analysis of case evidence of the four capabilities in the spatial domain also suggest variability in the developmental patterns across the eight participants. Case 5, the youngest participant, exhibited the first of the four capacities whereas the other seven participants demonstrated evidence of at least three of the core capacities. According Gardner (1991), the ability to recognize instances of the same element is "the most elementary operation, upon which other aspects of spatial intelligence rest".

Implications of the Study

Spatial abilities or visual-spatial thinking underlies all human activity (McKim, 1972). Educators and researchers in the field of education of the gifted must adopt reconceptualized definitions of giftedness (Maker, 1992a) or high competence (Gardner, 1983) and recognize that spatial ability is a multifaceted construct comprised of many independent and related skills that interact as an amalgam of abilities. This understanding of spatial abilities is vital if accurate assessment of the non-verbal cognitive abilities of special populations of highly capable individuals is to be realized.

The present study provided in-depth descriptions of spatial behaviors that could be observed and the spatial characteristics of products created by four young Hispanic children and four young Navajo children as they solved a meaningful block construction task. A clear picture of a child's spatial abilities can be depicted through careful observation of the solution strategies employed and the evaluation of the spatial representations of real world objects produced. Thus, as Gardner (1991) contends the symbolic patterns of behaviors of the four and five year old child's cognitive profile are quite distinctive and extend well beyond language.

Clear cultural differences in the spatial abilities and spatial characteristics of products were found, favoring the Navajo children. Similarly, qualitative differences were found in the eye patterns and solution strategies used by young children who were characterized as highly able problem solvers on the spatial task. Moreover, the behaviors noted and the characteristics of products created by Hispanic-Rural participants and the Navajo-Urban participants shed light on Gardner's theoretical propositions and provide evidence of the capabilities of spatial intelligence of children ages four and five from two distinct cultural backgrounds. Thus, this study added to the small body of research about the nature of problem solving and the spatial abilities of young culturally diverse children with gifts and potential gifts and talents.

Results of this study will be of interest to researchers who want to conduct studies using multiple case study design and qualitative methods of inquiry. Researchers need to understand, however, that the nature of this distinctive form of descriptive research is going to yield a small sample size because of the application of replication logic (Yin, 1994). Consequently, researchers must recognize the importance of (a) matching participants closely on the critical variables being examined (Borg & Gall, 1989); (b) reporting the subsample size as the true units of comparison when the sample is subdivided (Isaac & Michael, 1984); (c) converting quantitative results based on the subsample size and not the sample size in the statistical analysis; and (d) adjusting the variance accounted for effect size (Thompson, 1996). Under these conditions, researchers conducting qualitative studies with small samples can provide rich, descriptive information more efficiently than quantitative studies with a large sample size (Borg & Gall, 1989; Isaac & Michael, 1984). Moreover, researchers can address (a) the bias associated with small sample size or with small, distinct populations; and (b) the concern for the lack of rigor in investigations in the field of education.

Results of this study will be of interest also to educators who want to implement new approaches to individualize educational experiences for culturally diverse children, create meaningful, developmentally appropriate curriculum within a cultural context, and provide opportunities for young children to demonstrate spatial problem solving ability in the early childhood or kindergarten classroom. Educators can understand a great deal about young children's symbolic systems for representing their concrete, physical world by (a) observing how children, particularly those with potential gifts, manipulate and describe the products they create through play; (b) evaluating the spatial products they create; (c) allowing their students unlimited time to work on their spatial form or visual display throughout the school week; and (d) planning spatial exploration experiences in and outside of the classroom. A performance-based assessment and curriculum model has many advantages over traditional approaches because it provides many clues to the ways a child learns. The utility of the DISCOVER IV assessment model for the identification of children from culturally, linguistically, and geographically different backgrounds with high competence in the spatial area was evident in the present study. Additionally, this model was found to be a useful pre-intervention assessment tool to better understand how young children solve problems effectively and efficiently in spatial ways. This alternative assessment approach combined with multiple case study methodology provided robust, thick descriptions of the observed behaviors and products created by the eight, individual pre-kindergarten children and provided a comprehensive view of each child's unique, spatial cognitive profile and working style within a cultural context. The researcher was able to assess spatial dimensions of the whole child and detect distinct cultural differences involved in each participant's process of solving problems and creating symbolic representations of their concrete, physical world on a meaningful block construction task. Alternative assessment approaches for the identification of special populations of gifted children, such as the DISCOVER IV model used in this study, will enable teachers of young children to make informed curriculum decisions for their students based on ongoing classroom observations of the individual child's spatial strengths and interests. Thus, Maker's conception of giftedness can be applied within the framework of Gardner's theory of human cognition to create an effective alternative assessment model for the identification of young children from traditional Navajo heritage and young children from a traditional Hispanic heritage.

Suggestions for Future Research

More research is needed to further clarify and expand findings about the spatial field and domain of the intelligence through the problem solving of young children on a meaningful spatial task. Few examples of the ability to conjure up mental imagery and then transform that imagery were evident in the present study. Those that were evident, however, were couched in the verbalizations made by two of the eight participants.

Several directions for research are suggested by the present inquiry.

Clearly more case study research is needed to study intensively the problem solving and spatial abilities of young children with high competence or potential gifts from distinct cultural and linguistic backgrounds. Embedded multiple case studies are important to clarify, expand, and validate the findings of this investigation. Replicating the descriptive task analysis case studies using the same procedures would be important, comparing and contrasting young, gifted and non-gifted children ranging from 3 to 5 years of age. A study such as this would provide insight into (a) the spatial behaviors, problem solving, and spatial characteristics of 2-D and 3-D block constructions created by each child according to the four capabilities in the spatial area; (b) similarities and differences in the behaviors and products of preschool-aged children perceived as highly competent in the spatial area; (c) the nature of developmental differences in young children's construction of meaning in the non-verbal, symbol system of spatial representation through block play; and (d) patterns or "waves" of development and varied rates of development in the ill-defined spatial domain and the well-defined domains or "streams" of symbol use in young children across age levels. Similarly, an intensive, single-case study of the behaviors and products of a 7 year old child with high competence in the spatial area of intelligence with a severe visual impairment, for example, could provide insight into (a) the development of spatial intelligence and the set of problem solving skills and potential for problem creation in a young child with exceptional abilities; (b) the spatial thinking and spatial characteristics of products created by this unique individual as valued by the cultural and social institutions she belongs; (c) the child's spatial skill development, competence, working style, and interests within her or his socio-cultural milieu; and (d) the environmental interactions and rich early childhood experiences that fostered this child's potential gifts and talents in the spatial area.

Other studies suggested by the present study involve spatial problem solving and young children from different cultural backgrounds and geographical locations. More evidence is needed to determine, if indeed, young Navajo children living with their families on the reservation enter formal schooling as kindergartners with more advanced spatial abilities and problem solving skills. Future ethnographic investigations conducted in the naturalistic setting of a particular traditional tribal community, such as the home/school community of the Navajo children enrolled in the bilingual enrichment program in this study can provide distinct individual profiles of the children's spatial, non-linguistic experiences and shed light on the cultural values promoting high spatial competence in these young individuals. This line of empirical research should provide thick, accurate descriptions of the distinct patterns of behaviors, cognitive learning styles, and spatial characteristics of products created by young children living on the Navajo Reservation in Arizona. Furthermore, descriptive case and field studies can observation of various aspects of the environmental experiences and meaningful daily activities preschool-age children engage in within a naturalistic setting. More evidence is needed to determine whether or not differences in the spatial abilities and related skills of young children from different geographical locations favoring young rural children do exist. Researchers can compare and contrast the in-depth descriptions of visual-spatial orientation skills, for example, of male and female primary school children living with their families in rural areas with those of male and female primary school children living with their families in urban areas. In this way, in-depth descriptions of the spatial problem solving behaviors exhibited and the processes used by young, rural children and young, urban children can be obtained. Findings should shed light on the understanding of spatial problem solving of young male and female children with varied levels of experiences and activities within their respective environments.

In the present study, qualitative differences were noted also in the spatial behaviors and the quality of the spatial characteristics of the block constructions created by the Navajo-Rural participants and those of the Hispanic-Urban participants. It would be interesting to explore and understand the nature of problem solving behaviors that could be observed and the similarities and differences that exist across groups of young children differing in socio-cultural environmental experiences and living in families having different parenting styles related to the spatial field of the intelligence. Causal-comparative studies can be conducted to identify and investigate similarities and differences between cultural groups such as Navajo children (acculturated) living in an urban area and traditional Navajo children living on the Reservation or between young Hispanic-Urban children and young Hispanic-Rural children. Similarly, a causal-comparative study can be conducted to investigate the nature of problem solving differences found in the solution strategies of high spatial ability children and those of less spatially competent children. Additionally, research is needed to examine differences in the sequential patterns in the eye movement solution strategies used by young gifted and those used by non-gifted young children on an open-ended spatial problem solving task, such as the one used in the present study. This line of investigation can provide clarification and specific examples of similarities and differences in the spatial problem solving processes used by individuals from these two groups of young children. A related question for such a study is "do the visual-spatial analysis solution strategies used by young children with high competence in spatial problem solving contribute to differences in the quality of the products produced by individual children within the spatial ability groups?" If so, "are the identified patterns of solution strategy behaviors of the individual children related to differences in high competence in spatial problem solving or to differences in the individuals' range of developmental patterns of spatial problem solving skills?" Thus, empirical research along this line of inquiry can contribute to efforts to differentiate educational experiences for highly able young children from diverse backgrounds and provide for meaningful spatial opportunities that are both culturally, linguistically, and geographically appropriate.

Finally, quasi-experimental studies are needed to investigate the effectiveness of the DISCOVER IV assessment model for use in the identification of young gifted children from culturally different backgrounds. Similarly, studies are needed to determine the role a young, culturally different child's verbal abilities and nonverbal skills play in an educator's evaluation of that preschooler's spatial cognitive abilities and subsequent recommendation of the child for placement in the school district's program for gifted students. An evaluation of the DISCOVER IV bilingual enrichment programs also is needed so that inservice training and continuing education opportunities can be developed to assist educators in (a) developing new skills to facilitate spatial intelligence in young tribal and minority children with potential gifts and talents; and (b) valuing the visual-spatial thinking area as an equally important part of the early childhood and kindergarten curriculum in educational programs for gifted and potentially gifted young children.

Conclusion

Basic to a young child's intense desire to learn is problem solving and the spatial mode of thinking. Arnheim (1965) proposed that visual thinking or the ability to think in terms of pictures or physical images is indeed the most productive, creative thought process in any area of human cognition. This study comes from the premise that visual-spatial thinking is just as important as verbal abilities; therefore, the spatial mode of thought is indeed a necessary part of the educational experience and needs to be promoted in the schools if students are to realize their individual potential (Edgar, 1974) . However, until recently competence in the spatial area has not been recognized nor advanced in educational programs. Therefore, the spatial intelligence and problem solving abilities of young children need to be understood and appreciated as a cognitive construct of many qualities and characteristics that underlie all human activity that is not limited by language. Educators need to offer planned spatial opportunities beginning in the early childhood years and to recognize that the visual arts provide important instructional tools for learning. Public School educators across the country need to approach the arts by integrating drawing, painting, sculpting, designing, and technology that enhances visual-spatial thinking at all grade levels as an integral part of the academic curriculum. Clearly, omission of spatial experiences through problem solving and product creation continues to disadvantage special populations of the gifted, particularly those who are younger and those who are from diverse cultural and linguistic backgrounds. Thus, an understanding of spatial and problem solving processes of young children with high potential from diverse backgrounds should lead to the increased probability of culturally diverse and tribal students meeting eligibility standards of kindergarten and primary school programs for the gifted. Future research on spatial intelligence through observation of the problem solving of young children should move into the mainstream of education and inform educational policy for special populations of gifted students.

APPENDIX A

CASE STUDY PROTOCOL

Purpose

According to Yin (1994), the case study protocol is an essential data collection instrument to be used in a multiple case study design. This case protocol is intended as a guide to assist the researcher in the development of the data collection and analysis procedures to be used in conducting an individual case study. Thus, the protocol was delineated for purposes of preliminary planning of the pilot study. It is not intended to serve the entire multiple case study investigation.

The case study protocol is organized into four sections. First, the purpose of the investigation is presented and relevant readings are included. Second, the field procedures of the study are addressed. Third, the researcher delineated two sets of questions used in the initial planning of the investigation. In the fourth section, the researcher targets the audience for the investigation and delineates the format to be used in the composition of the case study report. The data collection and coding training manual completed the final section of the case study protocol.

Overview of the Case Study Project

The multiple case study investigation has a primary and secondary purpose:

1. To describe in depth the behaviors and products created by individual children, ages 4 through 5, from two distinct cultural backgrounds, on a pre-kindergarten problem solving task involving spatial intelligence. Eight separate case studies will be conducted. Hispanic and Navajo students are observed in their classroom and videotaped while actively engaged in a defined to more open-ended block construction activity, as a part of

the DISCOVER IV Assessment Model. Behaviors are measured by observing and recording the student's: a) physical movements; b) methods demonstrated; c) problems encountered, created, or defined; d) strategies employed; and e) verbalizations made. Product characteristics are measured by observing and recording: a) key spatial features of the product(s) during various stages of product development; and b) characteristics of the final product(s). For purposes of the case study protocol, we will be recording and coding the behaviors observed and product characteristics while viewing the video tapes of individual students on the Spatial Activity of the DISCOVER IV Assessment. We will also code for a category called "other".

2. To portray the core capacities involved in the spatial area of the intelligences as defined by Howard Gardner and exhibited by Hispanic children and Navajo children with varied spatial abilities who were enrolled in the DISCOVER IV bilingual enrichment project.

Relevant Readings

1. Frames of Mind: The Theory of Multiple Intelligences by Howard Gardner (1983).
2. Problem Solving: A Process Approach to Identifying Talent in Special Populations by C. June Maker (1991).
3. Creativity, Intelligence, and Problem Solving: A Definition and Design for Cross-Cultural Research and Measurement Related to Giftedness by C. June Maker (1993).
4. Giftedness, diversity, and problem-solving by C. J. Maker, J. A. Rogers, A. B. Nielson (1994).

5. Discover IV Process (Pre-K, Ages 3-5) by C. June Maker, A. B. Nielson, J. A. Rogers, & C. C. McArthur (1996).

Field Procedures

Overview of The Larger Research Project

This multiple case study is a smaller study under a larger, research project "designed to provide a developmental to provide a developmental bilingual enrichment program for preschool children who are potentially gifted or identified as gifted, and who have limited proficiency in English." (Maker, 1993). Project Discover IV: Discovering Intellectual Skills and Capabilities While Providing Opportunities for Varied Ethnic Responses is a Bilingual Education Special Populations Program developed by C. June Maker. This project was granted federal assistance funding from June, 1993 through August, 1996.

The University of Arizona and two Local Education Agencies (LEA) in Arizona developed two cooperative pre-kindergarten programs to benefit gifted minority children. Under the direction of Dr. Maker, project personnel assisted the LEA's in: (1) the use of the alternative assessment process to develop profiles of the children strengths and weaknesses in the seven areas of intelligence posited by Howard Gardner; and (2) the development of culturally appropriate curricula to nurture problem solving abilities in each domain of intelligence.

Using the framework of Gardner's theory, Maker and colleagues from the University of Arizona developed an innovative performance-based assessment model to select children for the program and to identify children with high learning abilities in the seven areas. As part of the assessment process, trained observers watch and interact with children engaged in problem solving tasks in the context of the classroom.

Obtaining Permission to Be Included as a Small Study Under the Larger Project

In the final year of the project, the researcher of the smaller study was a member of the assessment team of observers who administered the program assessments to the children at the close of the DISCOVER IV programs. The researcher's dissertation proposal was accepted by the members of her committee in April, 1996. The investigation was posed as a smaller study under the larger research project in progress. The smaller study was designed to analyze the set of videotapes recorded during the administration of the assessment process at the start of the DISCOVER IV programs. The study would focus on expanding the profiles of problem solving involving spatial abilities of the children the researcher selected from each project site.

Dr. Maker wrote a letter to the Human Subjects Committee, the University of Arizona, requesting permission for the researcher's dissertation project, Understanding Spatial Intelligence Through the Problem Solving of Young Children From Culturally Different Backgrounds: An Analysis of Behaviors and Products, to be included under the Bilingual Education Special Programs Project. In May, 1996, Dr. Maker received a letter of notification from the Human Subjects Committee approving her written request.

Storage and Retrieval of Case Data

Before the planning and conducting the pilot study, the researcher selected a computer software program as the basic storage and retrieval system for the dissertation project. FolioVIEWS, Version 3.1, (Folio Corporation, 1996) was purchased by the researcher to facilitate ease in storing and retrieving transcribed written text and in the coding of data from the Video Write-ups, Video Observation Summaries, and archival records for each individual case study file. This capability will be needed in completing data analysis throughout the multiple case study.

Case Study Questions

The researcher posed two sets of questions as a self-reminder to keep her on track as the collection of descriptive data proceeds. Data collection will focus on the behaviors and products of the four individual cases within each of the two case groups, for a total of eight separate case studies. These questions reflect the full set of concerns from the initial multiple case design, but they include only the questions to be addressed at the single-case level, not the sets of questions asked of the findings across multiple cases or those asked of the entire study as it relates to cross-case questions, within case-questions, theoretical questions, study implication questions, and future research questions.

Level 1: This set of questions will be asked of the DISCOVER IV Program Director and the Program Director's Assistant to locate the videotapes and archival records on the participants to be selected at the Urban program site and the Rural program site.

Q1. How are the videotapes and archival records filed on and stored and where are they located?

Q2. What are the procedures for accessing the video tapes to be viewed and the archival records to by read during the pilot study and to be analyzed during the main study?

Q3. How is the program at each site organized, who is the lead teacher at each site, and how are the two program sites the same or different from on another?

Q4. What are the demographics of the classroom students at each program site?

Level 2: This set of question will be asked of each individual case study. The answer to each question will come from three sources of evidence. The primary source of data will be the previously recorded videotapes on each participant in the real-life context of the classroom while being administered the Spatial Activity of the DISCOVER IV Assessment. The second source of data will be the Video Observation Spatial Activity notes completed by the observer who administered the assessment and recorded the individual's spatial, problem solving behaviors and final products created. The third and final source of data will be the archival records kept by the DISCOVER IV Program Director on each student in the pre-kindergarten classrooms. These individual records contain several documents: the Individual Plan, Classroom Observations, and the Classroom Teacher's Recommendations for the Gifted Kindergarten Program.

Q1. What are the demographics of the multiple case study participants?

Q2. What are the demographics of the three individuals who administered the spatial activity portion of the assessment to one or more of the participants?

Q3. How can the participant's behaviors observed be described for a single case study?

Q4. How can the products created by individual participant's be characterized for a single case study?

Q4. How can the core capacities of the spatial area of intelligence be depicted for a single case study based on the analysis of the multiple sources of evidence?

The Case Study Report

This section of the case study protocol reflects the researcher's preliminary thinking on the design of the final case study report for each single case study to be conducted. Since the researcher's dissertation committee constitutes the audience for this study, a standard linear-analytical approach to structuring the study will be followed in writing the case report.

The case report will be composed in a multiple case report format. The descriptive data that are collected and analyzed for a single case will be written in a traditional narrative form. The final version of the case study report will contain eight separate narratives. Furthermore, each narrative will be augmented with tabular and pictorial displays.

Data Collection and Coding Training Manual

Data Collection Procedures

Videotape Viewing Write-up

Descriptive data about behaviors observed and product characteristics for Cases 1 and 2 are to be collected during the pilot study by the researcher and the research assistant. They are to view each videotape separately, four consecutive times. The write-up process entails four stages of data collection.

Stage I provides an overview of the entire videotape (i.e. approximately twenty minutes of viewing). In Stage II, the videotape is viewed with **sound off** to collect diagrams of the student in the work space during the activity, sketches of the product characteristics at various stages of development, and the stages of product development. Stages III and IV, however, involve viewing the videotape with **sound on** to focus data collection on the behaviors observed.

Spatial Activity Summary

This procedure involves the reduction and synthesis of data collected. Immediately after completing the viewing write-up form, a written summary is made. The researcher and her assistant are to read the specific instructions, and independently complete the spatial summary form.

Case Analysis Summary

This procedure involves the development of statements summarizing the analysis of each case. Once the Video Viewing Write-up Notes and the Spatial Activity Summary are completed for Cases 1 and 2, the researcher will complete the Case Analysis Form. Subsequently, a colleague will read each of the three documents on individual Case 1 and then complete the case analysis form indicating agreement or disagreement with each statement. A written explanation will be given for any statements of disagreement. This step ensures that the analysis of each case is an accurate and reliable measure of the data collected.

Data Analysis Procedures

Code List

The researcher created a list of predetermined codes to be used in coding the transcribed data set for each case in the pilot study. The start list of codes derives from the research questions of the study. Descriptive labels for the general categories of the individual codes include: behaviors observed, characteristic features of the product(s) created, and the core capacities involved in spatial intelligence. As shown in Table A1, the initial list of codes specified in the pilot study are presented.

Table A1. The Preliminary Start List of Codes

Category	**Code**	**Research Question**
BEHAVIORS OBSERVED	**BO**	**1**
BO: PHYSICAL MOVEMENTS	BO-MOVE	
BO: METHODS	BO-METH	
BO: STRATEGY	BO-STRAT	
Unintentional problem	BOUNINPROB-STRAT	
Intentional problem	BOINTENPROB-STRAT	
Defined problem	BODEFPROB-STRAT	
PRODUCT CHARACTERISTICS	**PC**	**2**
PC: IN PROCESS OF DEVELOPMENT	PC-DEVELOP	
PC: FINAL PRODUCT	PC-FINAL	

<u>CORE SPATIAL CAPACITIES CSC 4</u> CSC: ABILITY-

RECOGNIZE INSTANCES CSC-SAME/ELEM

OF SAME ELEMENT

CSC: ABILITY-TRANSFORM/RECOGNIZE CSC-TRANS/ELEM

TRANSFORMATION OF ONE ELEMENT

INTO ANOTHER

CSC: ABILITY-CONJURE UP MENTAL CSC-MENTAL/TRANS

IMAGERY & TRANSFORM IMAGERY CSC-PRODUCELIKE/SPATINFO

CSC: CAPACITY- PRODUCE VISUAL

LIKENESS OF SPATIAL

INFORMATION

Definition of Codes

A code is defined as a single term that suggests different meanings to others. Therefore, the researcher and her assistant must understand the precise meaning of each code and be readily able to identify a segment fitting a definition of a code before coding transcribed text. For this reason, all codes must be defined operationally. The definitions of initial codes to be used in the pilot study include:

Behaviors observed are the descriptions of the participant's behaviors observed during the video viewing of individual students engaged in an open to more defined problem solving activity involving the spatial area of intelligence.
These behaviors are categorized as a) physical movements; b) methods used; and c) problems and strategies.

Physical movements are characterized as movements of the participants whole body within the work space and/or movements of the hands, fingers, legs, toes, head, chest, etc. used separately or involved in combination with parts of the body in the process of creating a finished product or products. For example, descriptions of the physical movements observed may include but are not limited to the following behaviors: the orientation of the participant within the work space during the entire activity, eye movements, hand preference, fine motor movements, gross motor movements, facial expressions, and any other physical movement behaviors observed.

Methods are characterized as the procedures used by the participant throughout the activity or his/her ways of exploring the blocks and work space in completing the spatial activity. For example, descriptions of methods used by the participant may include but are not limited to the following behaviors: comparison of block(s) with other block(s), rotation of block(s) or parts of product within block arrangement, layering of blocks, block reconstruction, verbalizations made to self, verbalizations made in response to the observer, or any other procedures observed to be used by the participant.

Problems and strategies are characterized as something difficult the participant has to deal with, understand, accomplish, or answer in the process of creating his/her final product(s) and the planning employed in solving or not solving problems during the spatial activity. Problems are categorized as either **unintentional, intentional, and/or defined**. Unintentional problems are those difficulties the student encounters by accident or by chance during various stages of the spatial activity. These problems occurred unexpectedly; they are problems that the student did not anticipate (i.e., the column of blocks toppled over when he reached for a specific block on the floor next to the display). Intentional problems are those difficulties the student creates or finds while working with the blocks during the activity. These problems are initiated by the student; they are problems that the student anticipated, planned, or discovered (i.e., she placed the rectangle block, horizontally on the apex of the triangle block). The strategies employed by the student included: trial and error (i.e., she placed the rectangle block horizontally on the slanted side of the triangle block) and block rearrangement (i.e., she placed the rectangle block in an upright, vertical position standing against the right edge of the triangle block). Defined problems refer to the verbalizations the student makes in an attempt to clarify, describe, or explain her understanding of the problem encountered or created. In instances of problem definition, the student provides a verbal statement about the problem to either herself or to the observer (i.e., "Did you forget? I'm gonna make my house.").

For example, descriptions of problems observed and strategies demonstrated may include but are not limited to the following behaviors: spatial planning of the layout or design, experimentation, self-talk, the number of attempts made in employing either a successful or unsuccessful strategy, or any other problems and strategies demonstrated by the participant.

Product characteristics are the sketches and descriptions that form the parts of the whole product created by the participant and or that show distinctive features of the final product as it evolves at various stages of development throughout the spatial activity. For example, the sketches made of the product and the descriptions recorded about the product may include but are not limited to the following characteristics: the number of blocks used, attention to the design or general arrangement of blocks that make up the finished product, the number of times a construction or part of it falls down, attention to detail with respect to the physical likeness of 3-dimensional version of an object(s) in real world surroundings or imaginary surroundings, sensitivity to size, proportion, balance, spatial layout, and/or geometric forms, verbal responses made about the final product, or any other characteristics of the product(s) created by the participant.

Core capacities involved in spatial abilities are the key components of the spatial domain of the intelligences that exist in various degrees across individuals. Examples of these spatial capacities can be found within various cultures. Howard Gardner has delineated four key capacities involved in spatial abilities:

1. The ability to recognize instances of the same element (i.e., a spatial form or a visual object). "The child related that the rectangle in the center of her display was a door leading to her bedroom."

2. The ability to transform or recognize a transformation of one element into another. "The boy picked up a triangular block, examined it carefully as he rotated it in space, then placed it on top of three rectangle blocks to create a tower as part the castle he said he was building."

3. The ability to conjure up mental imagery and then to transform that imagery. "The frequency of the child's eye movements increased in the direction of the ceiling prior to the reconstruction of fallen blocks in the block display."

4. The capacity to produce a visual likeness of spatial information (i.e., aspects of one's actual spatial experience in the creation of a spatial product, even in the absence of relevant physical stimuli). "She reported that her finished product was a "castle". Its physical appearance was strong and balanced similar to a medieval fortress."

Coding Guidelines

Coding involves the assignment of codes to segments of words from transcribed text. A code is a single term used to classify word segments into categories. Clauses, sentences, and paragraphs from the write-up and summary forms are the units of analysis for this study.

The researcher and her assistant are to code the transcribed text for each case according to the start list of codes and definitions. In addition, they are to apply the following rules of coding suggested by Miles and Huberman (1984):

1. Give a name to a code that is semantically as close as possible to the concept it represents.

   Example: motivation (concept) = MOT (code).
2. Do not include more than two or three aspects or parts to a single code.
3. Not every piece of the transcribed data set needs to be coded. Look for good examples of a code, not for all instances; unless, however, the frequency of the behavior to be coded is important.
4. Be sure that all codes relate to one another in coherent study-important ways.
5. Be ready to bend or revise codes whenever they look inapplicable, overbuilt, or overly abstract; however, do not change the codes too often.
6. Do not casually add, remove, or reconfigure codes.
7. Codes may be broken down into sub-codes. This will be necessary if a code increases or expands too much.
8. Dual coding is allowed if a segment is both descriptively and inferentially meaningful based on the research questions of the study.
9. Always code the previous set of transcribed write-up notes and spatial summaries before the next case data set is collected.

From the start list a master list of codes and subcodes will develop. The coded data will be clustered and ordered into a coding scheme. In other words, the coding and clustering of data for each case will drive the analysis of data in the study. The codes will change, develop, decay, or emerge progressively as the clustering of data in Case 1 continues. Together the researcher and her assist will analyze the groupings of coded data for emergent patterns or themes. The codes for patterns or themes are to be added tentatively to the list of codes. The researcher and her assistant are to test these pattern codes on the next set of transcribed text to see whether or not they are a "good" fit. This process of data analysis continues with the data set of transcripts from Case 2. Subsequently, a final list of codes and code definitions delineated after the analysis of data collected on the two individuals participating in the pilot study will serve as the coding instrument and coding definitions to be used in the main study.

Coding Reliability

Double-coding is important for two reasons. First, double-coding aids definition clarity. Definitions of codes become clearer when two individuals code the same data set. Discussion of initial disagreements lends itself to the expansion or revision of a definition. Second, double-coding is a good reliability check.

The reliability check procedure for this study involves several steps. First, the researcher and the research assistant are to code, separately, the viewing write-up and summary transcript for Case 1. Second, they are to review each of their coded transcripts together. They are to return to the videotape whenever inconsistencies are found to clarify their differences. Agreement by the researcher and her assistant must be reached on two key questions:

1. How big is a codable block of data?
2. Do they use the same codes for the same block of data?

Third, the researcher will record the total number of agreements and disagreements and calculate the percent of reliability between them. Initially, intercoder consistencies of at least seventy percent must be established before going on to the coding of the data set for Case 2. The same data collection, coding, and reliability procedures will be followed for Case 2 of the pilot study.

APPENDIX B

PROJECT DISCOVER IV ASSESSMENT:

SPATIAL PROBLEM SOLVING ACTIVITY

Overview

Maker, Rogers, & Nielson (1994) developed well-defined to open-ended problem solving assessment activities using attractive, versatile materials. Four activities were specifically designed to engage young children enrolled in the DISCOVER IV pre-kindergarten enrichment program to explore, manipulate, and demonstrate their interests and problem solving abilities in the linguistic, logical-mathematical, spatial, and musical intelligences. The child is invited to explore the materials for each activity while a trained observer follows the child's lead. When appropriate, the observer stimulates the child to take the activity to a different level or introduces another part of the activity. Each of these activities (i.e., storytelling/ linguistic, puzzle-solving/logical-mathematical, block building/spatial, and music-making/musical) are administered individually, and take approximately twenty minutes for the child to complete.

The trained observer can be the classroom teacher, teacher assistant, or any significant other who can establish rapport with young children. All the observers for the larger study, however, were members of the DISCOVER IV research team. They received instruction in how to implement each of the activities, including (a) watching videotapes of the entire assessment process, (b) discussing the actions of observers as well as several videotapes of children not enrolled in the program, (c) implementing the assessment process while being observed or while videotaping an assessment for later discussion by the novice and experienced observers, and (d) working to develop consistency in implementing the assessment procedures. The data collected during the observations of the child are combined with the information about the child during regular classroom activities to determine a child's strengths and interests in problem solving in the areas of the intelligences.

All of the assessment activities are administered in the classroom with the child situated on the floor. Bookcases or other furniture are used in defining the assessment area and creating adequate space for exploration and play. In this way, the child will not be distracted by others or things in an unfamiliar environment. The observer sits on the floor with the child. To ensure child-focused observations, each activity is videotaped and audiotaped, and photographs are taken of each product as it evolves.

The observer views the videotaped sessions of the child within two days after completing the assessment. Next, more detailed notes are recorded. Once completed, the observer submits the data to the project director. All assessment videotapes, audiotapes, film, and written observation notes are filed and stored for later retrieval and analysis.

The Spatial Problem Solving Activity

The problem solving activity involving spatial abilities is the assessment task with meaningful block materials. Involvement in this activity affords the teacher an opportunity to observe as a child demonstrates her problem solving and spatial abilities and creates either abstract or representational block constructions. The primary purpose of this activity is to elicit the student's non-verbal, spatial abilities. The problem solving of the child is important; therefore, the observer must maintain a supportive, non-interfering role.

Purpose

The purpose of this activity is to provide materials and an opportunity for the child to demonstrate her/his ability to create block constructions. These constructions can be either abstract or representational. Even though the child may be asked to tell about what she/he has made, the major purpose of the activity is to bring out the non-verbal, visual/spatial abilities of the child. The problem solving process is particularly important, so the observer must remain in a supportive, non-interfering role, watching carefully at all times.

Materials

The materials presented during the Spatial Activity include a set of unpainted, wooden blocks of various sizes and shapes, T. C. Timber Unit Block Set II, and a small felt ma (18" x 18").t. The set of Blocks is regular in shape so that certain combinations of blocks can equal one block shape or another combination of blocks.

Procedures

In general, the spatial activity involves observing the behaviors and final block constructions created while the child plays freely with the block set. Through out the activity, the observer makes sketches and takes photographs of the product or products the child creates at various stages of spatial form development, attending to all sides and angles of the block construction. After the child completes the activity, the observer records any problems encountered or created by the child , the solution strategies she employed, and the spatial characteristics of the final product(s).

The initial portion of the activity is titled: Free Exploration. Next, the Mat and Block part of the activity is introduced only if the child does not engage in free play with the blocks. Finally, the Tower part of the activity is introduced to the child if and only if the child did not play freely with the blocks or begin building a block construction. Each of the four tasks are summarized below.

I. **Free Exploration** - The observer takes the student to the area in the classroom where the video camera is set up. Once they are seated on the floor, records the beginning time on the sheet, and opens the box containing the blocks. The observer assist the child by taking the blocks out of the box. The observer invites the child to play with the blocks. No other instructions or prompts are given to the student. The observer remains silent for at least three minutes, even if the student does nothing. Careful and continuous observations of behaviors and products are made as the student begins to engage in block play. When the student is finished creating block constructions, the observer says: "Tell be about what you made." Once again the observer waits silently for at least ten seconds before repeating the statement or providing any encouragement. The observer listens intently to the student's verbalizations.

II. **Mat and Bocks** - If the student has not engaged in block play, the observer unfolds the felt mat and places it in front of him. The observer presents ten blocks of various shapes and sizes, and then says: "Pretend the mat is a piece of ground and you are a builder who has these pieces of wood. What would you like to build on this piece of ground? You can build anything you like?" The observer waits silently for at least three minutes. Once the student begins block building, the observer resumes careful observation.

III. **Tower** - This part of the activity is introduced only if the student did not yet engage in block play and construction. The observer says: "Let's build some towers together." The observer begins to build a tower slowly. Encourage the student to assist in the building of the tower and allow the student to take the lead as soon as possible. The observer stops building and resumes careful observation.

IV. **You make...I make** (optional) - This part of the activity is to be used to stimulate more block building if the observer feels that she has not tapped into the student's interest in problem solving with the spatial activity materials. The observer says: "Let's build together. This time, you make something and then I'll try to make it. I'll make whatever you make." Once again, the observer waits silently for three minutes. Ten seconds later, the observer repeats the instruction. Follow the student's lead once he begins to build with the blocks. The observer begins to build, copying the student's construction. The observer resumes careful observation, stopping to take photographs of the constructions. When the student is finished building, the observer says: "Tell me about what you made. How do you think I did?"

At the close of the spatial activity, the observer records the ending time, thanks the student praising him for the interesting constructions he made, and puts the blocks back into the box.

More information about the DISCOVER IV(Pre-K, Ages 3-5) assessment model and the unpublished document including the complete description, procedures for administering each of the activities, the data collection forms used for making sketches and recording notes about the child's problem solving processes, and the list of required materials may be obtained by contacting Dr. June Maker, DISCOVER Project Director, SERSP, Room 439, P. O. Box 210069, Tucson, AZ, 85721.

APPENDIX C

FORMS DEVELOPED IN THE PILOT STUDY

Overview

The five forms included here were developed, revised, and refined as part of the pilot study. These forms were used in the collection and reduction of data, and throughout the various stages of data analysis completed as part of the study. Each contains the purpose, procedures, guidelines, and recording sheets used by the researcher throughout the investigation.

Participant Pool Selection Form

Study: __ Pilot
__ Main
Case Study #:

Today's Date: __ /__ /__

Site: __ Urban Site
__ Rural Site

Gender: __ **female**
__ **male**

STEP I
Racial and Ethnic Identity: __ Black/Non Hispanic
__ White/Non Hispanic
__ Hispanic or Mexican American
__ Native American
__ Asian/Pacific Islander or Oriental

Language of Instruction in the Classroom:

Date Assessed: __/__/__

DOB: __/__/__

CA: __ yrs., __ months

Initial Participant Selection Criteria:

Y N 1. Participant is either Hispanic/Mexican American or Navajo.

Y N 2. Participant's age at the time of the assessment was between 4 years, 0 months through 5 years, 3 months.

Y N 3. A complete videotaped recording of the Spatial Activity and accompanying Observer's Notes were stored and available for viewing by the researcher.

If Y was indicated above for 1-3, then complete page 2 of the form. If N was indicated above on either 1, 2, or 3, then the individual is no longer eligible to participate in the study.

STEP II
Observed By:

Videotape #:

Start of Tape Counter #:

End of Tape Counter #:

Total Minutes Participant Involved in Activity: __ mins.

Selection Criteria for Quality Videotapes of Participant:

Y	N	1.	Clear view of participant during the Spatial Problem Solving Activity
Y	N	2.	Clear view of product(s) created by participant
Y	N	3.	Audible responses of the participant in either English, Spanish, or Navajo.
Y	N	3a.	If N, then audible response of the participant on the audiotape accompanying the videotaped session.

__ MET THE SELECTION CRITERIA TO PARTICIPATE IN THE RESEARCH STUDY (i.e. Y indicated on 1, 2, 3, or 1, 2, or 3a).

__ DID NOT MEET THE SELECTION CRITERIA TO PARTICIPATE IN THE RESEARCH STUDY (i.e. N indicated on 1, 2, 3 and/or 3a).

STEP III
Final Selection of Participants:

__ COMPLETED STEP I AND STEP II OF THE PURPOSEFUL SAMPLING PROCEDURE AND PARTICIPATED IN THE SIMPLE RANDOM SAMPLING METHOD USED TO DRAW THE PARTICIPANTS FOR THE RESEARCH STUDY BUT WAS NOT SELECTED AS A PARTICIPANT FOR EITHER THE PILOT STUDY OR THE MAIN STUDY.

__ WAS DRAWN AS ONE OF THE TWO PARTICIPANTS FOR THE PILOT STUDY.

__ WAS SELECTED AS ONE OF THE SIX ADDITIONAL PARTICIPANTS FOR THE MAIN STUDY BASED ON GENDER AND/OR HIGH SPATIAL COMPETENCY.

Video Observation Write-up Notes Form

PILOT STUDY __
MAIN STUDY __

PROGRAM SITE:
ASSESSMENT DATE:

CASE STUDY #: __

VIDEO TAPE #:
VIEWING DATE:

Participant's Name:

CA: __ years, __ months
Ethnicity:
Gender:
Primary Language:

Viewer's Name:

CA: __ yrs.
Ethnicity:
Gender:
Primary Language:

Purpose: This form is to be used for the collection of data to be coded for each case after viewing the videotape of the spatial activity of the DISCOVER IV Observation Process. This is the first level of data analysis to be completed.

STAGE I: FIRST VIEWING

Directions: Overview of Videotape

This initial stage of the collection of data requires only that an overview of the videotape be completed. The videotape is to be watched in its entirety (i.e. approximately ten to twenty minutes).

First, fill in the blank line below with the name of the activity you viewed: Part I - FREE EXPLORATION, Part II - MAT & BLOCK; Part III - TOWER, or Part IV - YOU MAKE....I MAKE.

SPATIAL PROBLEM SOLVING ACTIVITY:

Next, record the beginning time indicated on the videotape at the start of the viewing session.
BEGINNING TIME: ___

After viewing the videotape, record the ending time indicated on the videotape at the end of the viewing session.
ENDING TIME: ___

Subsequent stages of the video viewing/data collection process are delineated below. For **Stages II - IV**, the video tape is to be viewed three additional times. View the videotape in increments of one to two minutes. After each segment of viewing, stop or pause the videotape and record specified data on the sheet according to the instructions provided under each stage.

STAGE II: SECOND VIEWING WITH SOUND OFF

Directions: Product(s) Created

For this stage of the viewing procedure, **please be sure to record the following**: (a) a diagram of the work space and the orientation of the participant within the work space throughout the activity; (b) number of the stage of the activity and sketches of the product as it evolves at various stages of development; (c) a detailed written description of each stage of product development; and (d) a written account of the key features of the product as it evolves and the characteristic features of the final product(s).

Product characteristics **to be included but not limited to the following distinctive features**:

Number of blocks used, attention to the design or general arrangement of blocks that make up the finished product, the number of times a construction or part of it falls down, attention to detail with respect to the physical likeness of 3-dimensional version of an object(s) in real world surroundings or imaginary surroundings, sensitivity to size, proportion, balance, the spatial layout, and/or geometric forms.

Use the red felt tip pen provided to record next to the sketch in each stage of the process the number of times the block construction/layering or part of it fell down.

Once the recording of data is completed, begin Stage III of the viewing procedure.

Stage II

I DIAGRAM	II STAGE	III SKETCH	IV CHARACTERISTICS

(Stage II - Continued)

I	II	III	IV
DIAGRAM	**STAGE**	**SKETCH**	**CHARACTERISTICS**

STAGE III: THIRD VIEWING OF VIDEOTAPE WITH SOUND ON

DIRECTIONS: Behaviors Observed

In this stage of the viewing procedure, you are to: (a) number each stage of the process; and (b) record detailed written descriptions of the participant's behaviors.
Physical movements observed **to be included but not limited to the following:**

eye movements, hand preference, fine motor movements, gross motor movements, facial expressions, and any other physical movements observed.
Methods observed **to be included but not limited to the following:**

comparison of block(s) with other block(s), rotation of block(s) or parts of product within block arrangement, layering of blocks, procedures used in block reconstruction, verbalizations made to self, verbalizations made in response to the observer, and any other methods observed.

Once the recording of data is completed, begin Stage IV of the viewing procedure.

Stage III

I STAGE	II MOVEMENTS	III METHODS	IV VERBALIZATIONS

(Stage III - Continued)

I	II	III	IV
STAGES	**MOVEMENTS**	**METHODS**	**VERBALIZATIONS**

STAGE IV: FOURTH & FINAL VIEWING OF VIDEOTAPE WITH SOUND ON

DIRECTIONS: Problem Solving & Strategies

In the final stage of the viewing procedure, **please be sure to number the stage of the activity and record detailed written descriptions of the problem solving, problem finding, and problem defining strategies demonstrated** by the participant during each stage of the activity.

Strategies demonstrated **to be included but not limited to the following**:

unintentional problems encountered, intentional problems created or found, the problem solving strategies used when unintentional problems were encountered, the problem finding strategies used when intentional problems were created or found, the number of attempts made in employing the strategy and whether or not the strategy employed was successful, verbalizations made when describing or defining the problem to self and/or to the observer.

Use the markers provided to color code types of problems in the following manner:

1. **Yellow = unintentional problem encountered**

2. **Orange = intentional problem created or found**

In addition, use the red felt tip pen provided to record next to each strategy the number of times a specific strategy was attempted and if the strategy employed was successful or unsuccessful.

Once data are recorded, **please be sure to reread the write-up for Stage I - IV of the viewing write-up notes making any corrections and/or additions as needed.** Then, complete the write-up summary on pages 18-20.

Stage IV

I STAGE	II PROBLEM	III STRATEGY	IV VERBALIZATIONS

(Stage IV - Continued)

I STAGE	II PROBLEM	III STRATEGY	IV VERBALIZATIONS

SUMMARY OF OBSERVATION DATA COLLECTED

Directions: **Please review all data collected above before completing the data summary sheets. This information will be used in calculating inter-rater and intra-rater reliability.**

Stage I Summary

A. Total Viewing Time: ___ minutes

Stage II Summary

A. Total # of Stages involved in product development: ____

B. List and describe each stage of product development:

C. Total # of products created by the participant: ____

Product Descriptions Page # of Sketch

D. Total # of times parts of the display fell down: ____

E. Total # of times the whole display fell down: ____

Stage III Summary

A. List the methods observed through out the spatial activity:

Stage IV Summary

A. Total # of times **unintentional problems** were observed:____

B. Total # of times **intentional problems** were observed: ____

C. Total # of times problems were **defined** to self or to others: ____

Give several examples that best represent each of problems A, B, and C.

Page #	Problem Description	Strategy Description	Effective? (Y/N)

D. Provide any other comments of interest relevant to the behaviors observed and/or the product(s) created by the child:

Spatial Activity Summary Form

Participant's Name:

Case Study #: Program Site:

CA: Video #:

Ethnicity: Today's Date:

Gender: Written By:

Assessment Date: **Pilot Study __ Main Study __**

Purpose: The **Spatial Problem Solving Process Coding Instrument** is to be used in completing this form for the purpose of second level data analysis.

Directions: **Please read and review the data collected on pages 4-20 of** your video observation write-up notes and the print outs of coded data for this case. Then **provide a summary for each of the research questions on the pages to follow**.

Research Question 1 - BEHAVIORS OBSERVED

1. How would you describe the behaviors observed by the participant you viewed on the videotape? In your own words, please summarize: (a) the physical movements you observed, including the student's body orientation within the work space; (b) the methods you observed the participant using throughout the various stages of product development; and (c) the kinds of problems and the strategies observed and whether the strategies demonstrated by the student were successful or unsuccessful.

   a. **Summary: Physical Movements Observed**

   b. **Summary: Methods Observed**

   c. **Summary: Problems & Strategies Observed**

2. Please feel free to include anything else that struck you as salient, interesting, or important about the behaviors observed as they relate to the participant's problem solving in the spatial area.

Research Question 2 - CHARACTERISTICS OF PRODUCTS CREATED

1. How would you describe the characteristics of the product(s) created by the participant you observed while viewing this videotape? In your own words, please summarize: (a) features of the whole display or parts of the display at various stages of product development; and (b) characteristic features of the final product(s).

   a. **Summary: Product Development**

   b. **Summary: Final Product**

Research Question 4 - GARDNER'S CORE CAPACITIES OF SPATIAL INTELLIGENCE

Gardner proposes that there are core capacities involved in spatial intelligence and that these exist in various degrees across individuals. Are the data collected on this case suggestive of the existence of the core capacities? If Y is indicated for any of the capacities delineated below, then make an inference for each.

Y N a. the ability to recognize instances of the same element (i.e., a spatial form or a visual object).

Y N b. the ability to transform or recognize a transformation of one element into another.

Y N c. the ability to conjure up mental imagery and then to transform that imagery.

Y N d the capacity to produce a visual likeness of spatial information.

Archival Document Summary Sheet

Carefully read the entire document. Then, reread the document a second time to highlight information on the document that is relevant to the individual case and complete the form. Attach the completed form to the document and place in the participant's case file.

Case Study #: __

Gender:

Age:

DISCOVER IV **Site:** __ Urban Site

__ Rural Site

Date received: __________

Completed by: __ Teacher

__ Parent

__ Teacher Assistant

__ DISCOVER IV Research Team Member

Name or description of document:

Significance or importance of document:

Event with which document is associated:

Date of Event: __________

Coding Reliability Check Form

Today's Date: / /

Study: __ Pilot
__ Main

Case Study#:
Site: __

Urban __

Rural __

Reliability Check: __ Intercoder

__ Intracoder/Code-recode

Divide the number of agreements by the total number of agreements plus disagreements, times 100.

$$\frac{\text{\# of agreements}}{\text{total \# of agreements + disagreements}} \times 100 =$$

Calculate the intercoder reliability.

A RELIABILITY OF ___ PERCENT(%) WAS CALCULATED FOR THE CODED TRANSCRIPT(S).

AGREEMENTS

Coded Data ____ Page _____

TOTAL # OF AGREEMENTS: ____

DISAGREEMENTS

Coded Data ____ **Page** _____

TOTAL # OF DISAGREEMENTS: ____

APPENDIX D

CODING INSTRUMENT, DEFINITIONS, AND EXPANDED CODES

SPATIAL PROBLEM SOLVING CODING INSTRUMENT

Category		Code	Research Question
BEHAVIORS OBSERVED		BO	1
BO:	**UNRELATED MOVEMENTS**	**BO:UNMOVE**	
BO:	**UNRELATED VERBALIZATIONS**	**BO:UNVERB**	
BO:	**IMPLEMENTATION STRATEGIES**	**BO:STRAT**	
	BO: Block Manipulation	*BO:STRAT-BMANIP*	
	BO: Product Modification	*BO:STRAT-PMODIF*	
	BO: Product Transformation	*BO:STRAT-PTRANSFORM*	
	BO: Physical Adjustments	*BO:STRAT-PHYSADJUST*	
	BO: Methods	*BO:STRAT-METHOD*	
BO:	**PROBLEM TYPES**	**BO:PROBS**	
	BO: Unintentional	*BO:PROBS-UN*	
	BO: Intentional	*BO:PROBS-INTENT*	
BO:	**EXPRESSION OF EMOTION**	**BO:EMOT**	
	BO: Physical	*BO:EMOT-PHYS*	
	BO: Verbal	*BO:EMOT-VERB*	

CHARACTERISTICS FINAL PRODUCTS		CFP	2
CFP:	**DEVELOPMENT OF PRODUCT**	**CFP:DEVEL**	
	CFP: Stages	*CFP:DEVEL-STAGE*	
CFP:	**KEY FEATURES**	**CFP:KEYFT**	
	CFP: Representation	*CFP:KEYFT-REPRESENT*	
	CFP: Artistry	*CFP:KEYFT-ART*	
CORE SPATIAL CAPACITIES		CAPS	4
CAPS:	**TO RECOGNIZE INSTANCES OF SAME ELEMENT**	**CAPS:RECSAME**	
CAPS:	**TO TRANSFORM/RECOGNIZE TRANSFORMATIONS OF ONE ELEMENT INTO ANOTHER**	**CAPS:RECTRANS**	
CAPS:	**CONJURE UP MENTAL IMAGERY & TRANSFORM IMAGERY**	**CAPS:MENTAL**	
CAPS:	**PRODUCE VISUAL LIKENESS OF SPATIAL INFORMATION**	**CAPS:VISLIKE**	

CODE DEFINITIONS

Behaviors Observed - BO

Unrelated movements: BO:UNMOVE	The physical movements the participant makes during the spatial activity that seem random or not pertinent to the problem solving process.
Unrelated verbalizations: BO:UNVERB	The utterances that are made by the participant, to self or others within or outside the work space, that seem random or not pertinent to the problem solving process.
Implementation strategies: BO:STRAT	The ways that the participant accomplishes the spatial activity; the strategies and methods in participant employs in creating a product or products during the problem solving process.
Problem types: BO:PROBS	The kind and/or variety of problems or difficulties the participant either encounters unexpectedly or discovers purposefully while involved in the product creation/problem solving process.

Expression of emotion: BO:EMOT	The verbalizations and physical presence of the participant which reveal her attitudes and feelings (e.g. enjoyment) about the spatial activity. Specifically, the physical movements, gestures, facial expressions, body posture, body space requirements, eye contact, voice tone and inflection, rate of speaking, habitual mannerisms, laughter, or other utterances the participant makes to herself or directs to the observer.

CHARACTERISTICS FINAL PRODUCTS - CFP

Development of product: CFP:DEVEL	The stages of development or the progression of changes to the appearance of the whole and/or parts of the product or series of products created by the participant.
Key features: CFP:KEYFT	Important spatial aspects and/or notable abstract spatial elements utilized by the participant in the making of the product depicting his/her world.

CORE SPATIAL CAPACITIES - CAPS	
To recognize instances of same element: CAPS:RECSAME	This is the first of four spatial capacities posited by Gardner. It is the ability to recognize instances of the same element or spatial form of an object.
To transform/recognize transformations of one element into another: CAPS:RECTRANS	This is the second of four spatial capacities posited by Gardner. it is the ability to transform or recognize a transformation of one element into another.
Conjure up mental imagery and transform imagery: CAPS:MENTAL	This is the third of four spatial capacities posited by Gardner. It is the ability to conjure up mental imagery and then to transform that imagery.

Produce visual likeness of spatial information:

CAPS:VISLIKE

This is the fourth and final spatial capacity posited by Gardner. it is the capacity to produce a visual likeness of spatial information or aspects of one's actual spatial experience in the creation of a spatial product, even in the absence of relevant physical stimuli.

EXPANDED CODES

1. Unrelated Movements

2. Unrelated Verbalizations

3. Implementation Strategies

3.1 block manipulation

3.1.1 positioning,repositioning, and/or substituting of block(s)

3.1.1.1 placement of block(s)with intent (e.g. to steady blocks, to shadow blocks, to replace a particular block or grouping of blocks)

3.1.1.2 other

3.1.2 tactile exploration and/or experimentation with block(s) before, during, or after placement

3.1.2.1 touching/feeling block surfaces with finger(s), hand(s), or other body parts

3.1.2.2 rotating block(s) in space with finger(s), hand(s), or other body parts

3.1.2.3 flicking, pushing, or sliding blocks with finger(s), hand(s), or other body parts to effect block movement

3.1.2.4 other

3.2 product modification

3.2.1 layering block groupings of same or different geometric forms

3.2.1.1 vertically

3.2.1.2 horizontally

3.2.1.3 other

3.2.2 adding and/or subtracting block(s)

3.2.2.1 to complete an open space or block pattern

3.2.2.2 to create a larger geometric form from smaller same shaped forms (e.g. two right angle blocks = one large triangle)

3.2.2.3 to increase and/or decrease slope, height, length, or width

3.2.2.4 to make the construction into something different (e.g. house to castle)

3.2.2.5 other

3.2.3 rebuilding block part(s) and/or section(s) of the construction

3.2.3.1 to create functioning aspect(s)

3.2.3.2 to strengthen or balance

3.2.3.3 to reconstruct after falling down

3.2.3.4 to incorporate remaining blocks or to incorporate unique blocks (e.g. bridge shape, the half moon shape)

3.2.3.5 to use negative or empty space as part of the construction

3.2.3.6 other

3.3 product transformation

3.3.1 adding and/or subtracting specific block(s)

3.3.1.1 to change the proportion overall

3.3.1.2 to create or change symmetry or asymmetry of the layout overall

3.3.1.3 to add detail or embellish the design overall

3.3.1.4 other

3.3.2 remaking or starting over the original construction

3.3.2.1 to replicate the original product created

3.3.2.2 to create variation(s) of the original construction or theme

3.3.2.3 to change the orientation or the location of the original construction

3.3.2.4 to create a new construction by combining two or more constructions

3.3.2.5 other

3.4 physical adjustments

3.4.1 of body position within available work space

3.4.1.1 ability to isolate and use different gross motor body parts effectively(e.g. uses foot as a tool)

3.4.1.2 to plan, sequence, and execute moves efficiently (e.g. repositions self to increase work space, works around perimeter, increases or decreases height to match construction, intentionally remains in same position)

3.4.1.3 other

3.4.2 of eyes and head

3.4.2.1 to search work space for specific geometric forms to complete pattern or construction

3.4.2.2 fixes gaze on block, pattern, section, or whole construction and visually rotates in space without manipulation

3.4.2.3 awareness and knowledge of self, others, and or objects within the immediate environment (e.g. visually tracks observer or own movements within work space, visually tracks others outside of work space)

3.4.2.4 towards object within work space (e.g. box, wall, cabinet, pile of blocks, construction(s))

3.4.2.5 other

3.4.3 of arms & hands

3.4.3.1 selecting, grasping, or placement of block(s) with either hand independently or with both hands simultaneously

3.4.3.2 crosses midline to transfer or place block(s)

3.4.3.3 ability to isolate and use different fine motor body parts (e.g. uses finger(s)as a tool)

3.4.3.4 other

3.5 methods

3.5.1 problem solving approach to spatial activity

3.5.1.1 uses organized, systematic approach

3.5.1.2 continuously working/ demonstrated interest in activity

3.5.1.3 uses and learns from a trial-and-error

3.5.1.4 compares blocks and analyzes spatial information in the environment (e.g. blocks represent actual objects, points to various rooms or route specific to the layout of construction representing own home)

3.5.1.5 other

3.5.2 spatial planning

3.5.2.1 recognizes, finds, and incorporates same geometric form/pattern based on spatial elements of blocks (e.g. shape, size, thickness)

3.5.2.3 appears to refer to a central concept (e.g. proportion, balance) or theme (e.g. to replicate layout of own home or dragon seen in a book)

3.5.2.4 makes construction in a spatial way (e.g. makes outline and fills in, uses negative space)

3.5.2.5 uses and learns from exploration (e.g. explores cause/effect relationship)

3.5.2.4 other

3.5.3 verbal planning

3.5.3.1 defining a problem to self or observer

3.5.3.2 to explain or confirm to self and observer

3.5.3.3 to question self or observer

3.5.3.4 to create sound effects to enhance construction

3.5.3.5 other

4. Problem Types

4.1 unintentional

4.1.1 block orientation

4.1.1.1 block alignment inside or outside box hinders search & selection

4.1.1.2 unbalanced block arrangement

4.1.1.3 other

4.1.2 body orientation within proximity of product

4.1.2.1 repositioning of body or parts of body

4.1.2.2 other

4.2 intentional

4.2.1 purposeful body orientation

4.2.1.1 preference to remain stationary

4.2.1.2 hand preference

4.2.1.3 other

4.2.2 intent on a specific geometric form

4.2.2.1 the fit of a particular block

4.2.2.2 the arrangement of a particular block or sequence/order of blocks

4.2.2.3 to incorporate a remaining block or block set in the design

4.2.2.4 other

5. Expression of emotion

5.1 physical

5.2 verbal

5.3 other

6. Development of product

6.1 stages

6.1.1 simplistic process

6.1.1.1 four or less stages

6.1.1.2 less than four modifications made

6.1.1.3 minor transformations made

6.1.1.4 few if any transformations made

6.1.1.5 uses at least half of the blocks

6.1.1.6 more than two products created

6.1.1.7 other

6.1.2 complex process

6.1.2.1 more than four stages of development

6.1.2.2 four or more modifications made

6.1.2.3 major transformations made

6.1.2.4 many transformations made

6.1.2.5 uses all or the majority of the blocks

6.1.2.6 no more than two products created

6.1.2.7 other

7. Key features of final product

7.1 representation

7.1.1 creates recognizable symbols for common objects and coordinates spatial elements into unified wholes (e.g. buildings, vegetation, animals, people, vehicles)

7.1.2 uses realistic proportion, features (e.g. closed roof, open entryway) and/or deliberate choice of blocks or block patterns

7.1.3 other

7.2 artistry

7.2.1 shows sensitivity to various lines of force or use of various elements of art (e.g. shape, balance) to produce certain effects (e.g. final product appears "powerful")

7.2.2 shows sensitivity to detail and embellishment

7.2.3 is flexible and inventive in use of blocks (e.g. experimental with blocks or use of negative space)

7.2.4 recognizes and uses spatial element of blocks to create a variety of geometrical forms

7.2.5 executes a range of subjects or themes depicting symbols or real/imagined scenes (e.g. map or diagram of a castle, farm landscape)

7.2.6 other

8. Spatial Capacities

8.1 ability to recognize instances of same element

8.2 ability to transform or recognize transformations of one element into another

8.3 ability to conjure up mental imagery and transform that imagery

8.4 capacity to produce a visual likeness of spatial information

APPENDIX E

SKETCHES OF THE FINAL PRODUCTS CREATED BY PARTICIPANTS

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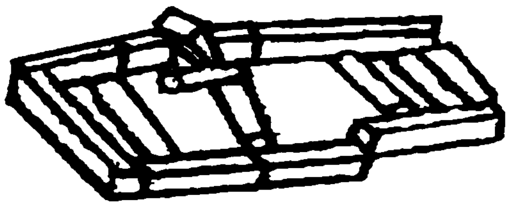

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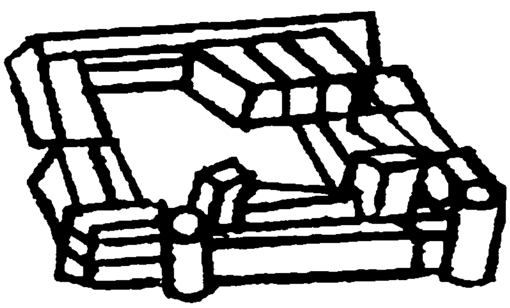
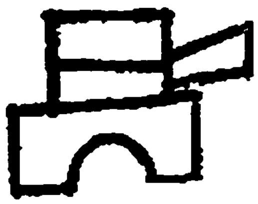


Figure 2. Participant 3-Final Product.

(a)



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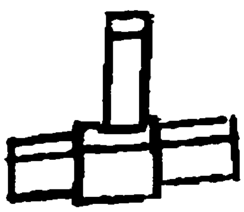

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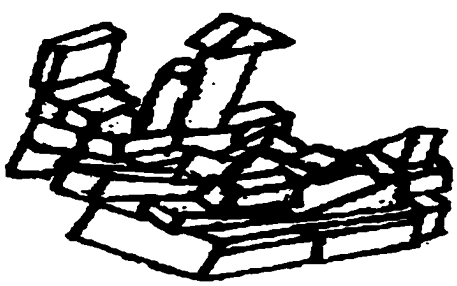
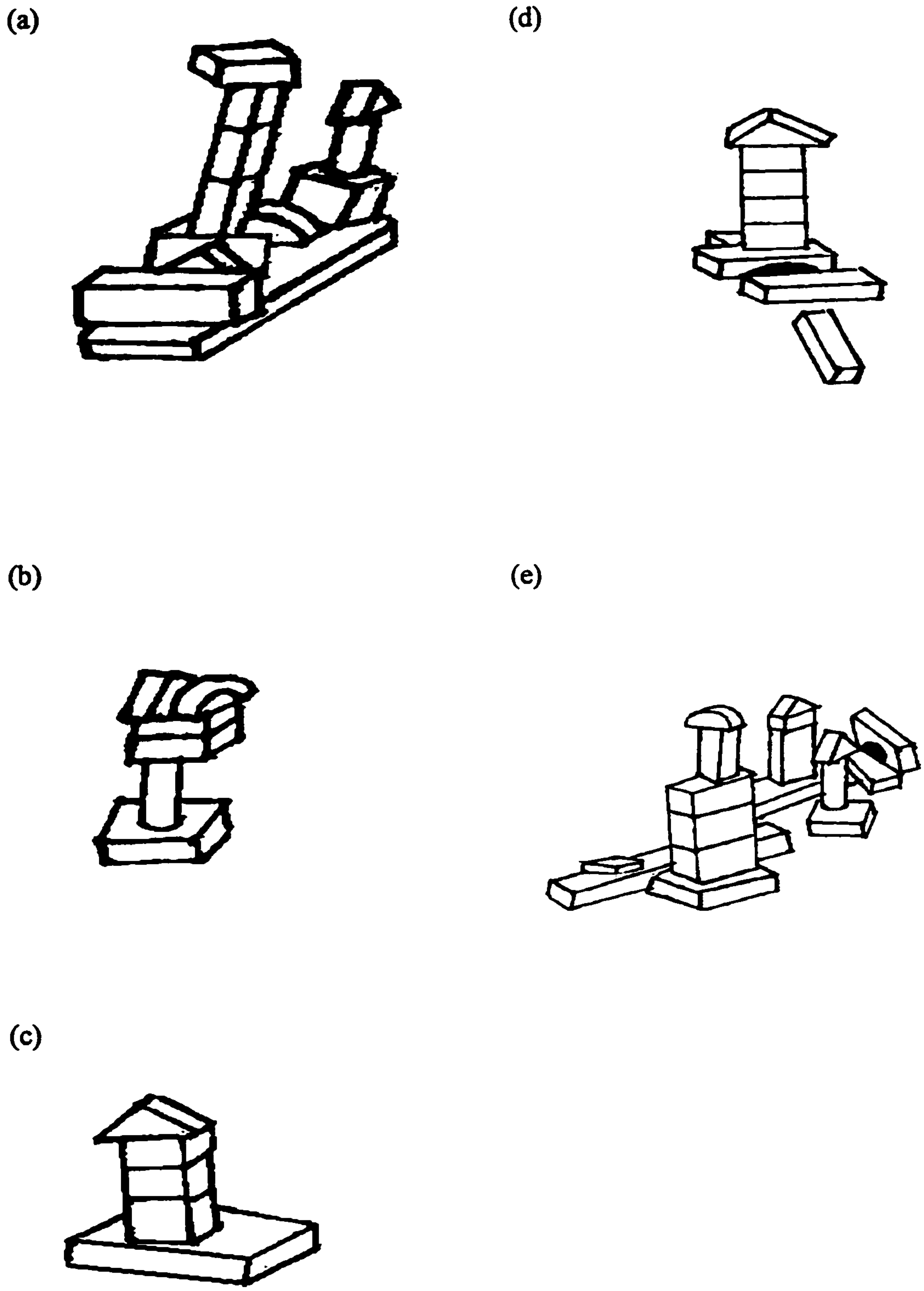


<u>Figure 3.</u> Participant 4–Final Product.



<u>Figure 4.</u> **Participant 5-Final Product.**

(a)

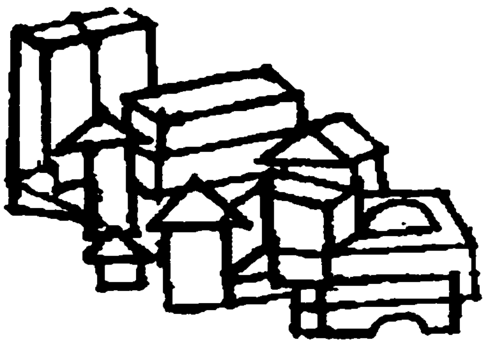
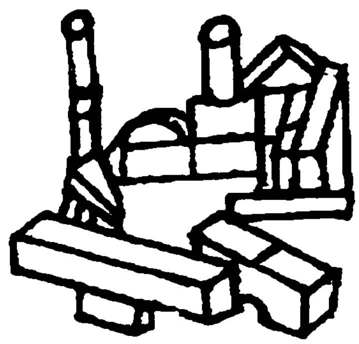


Figure 5. Participant 1-Final Product.

(a)



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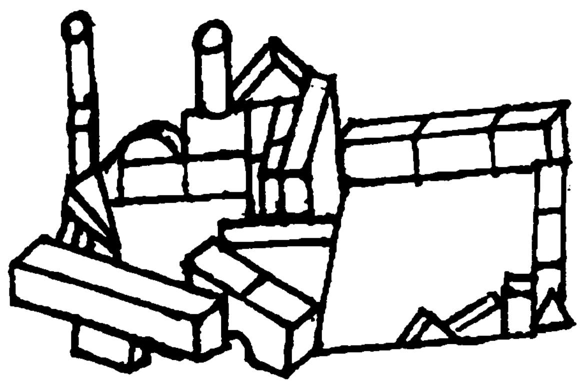


Figure 6. Participant 2-Final Product.

(a)

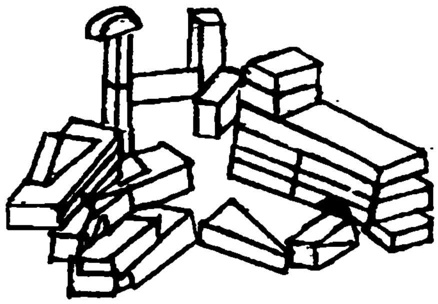


Figure 7. Participant 6-Final Product.

(a)

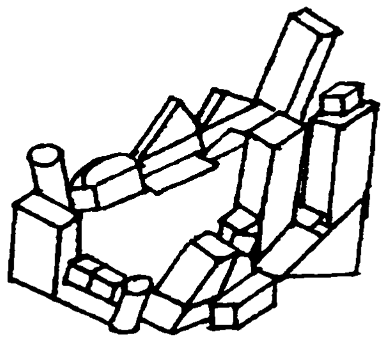
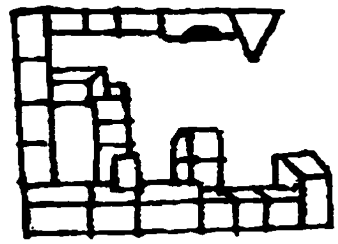


Figure 8. Participant 8-Final Product.

(a)



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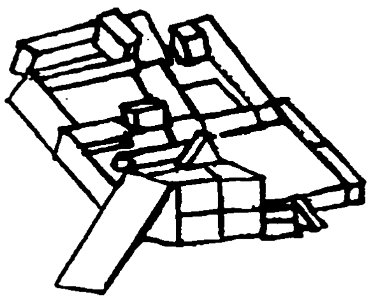

Figure 9. Participant 7-Final Product.

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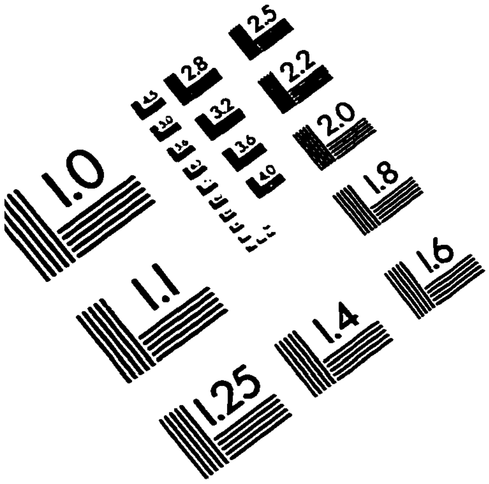
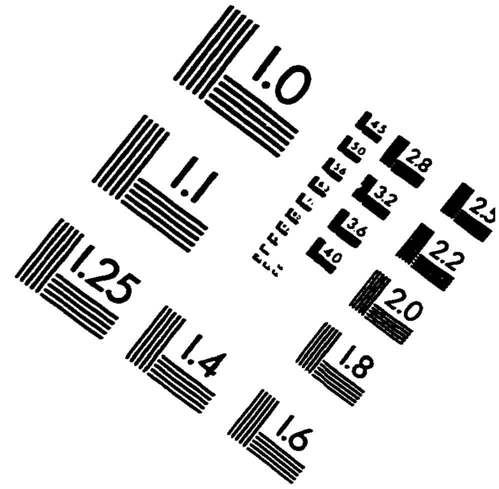
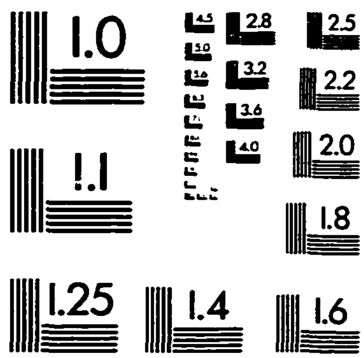
IMAGE EVALUATION TEST TARGET (QA-3)







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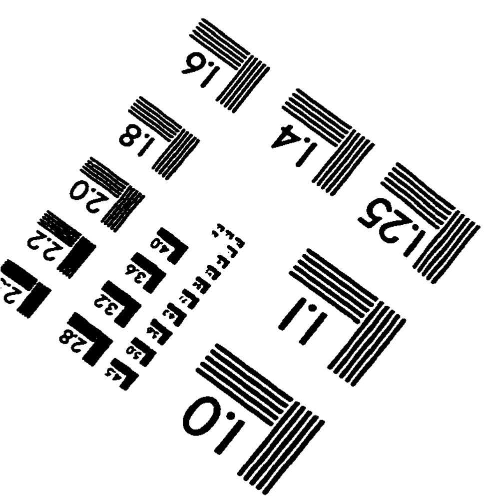

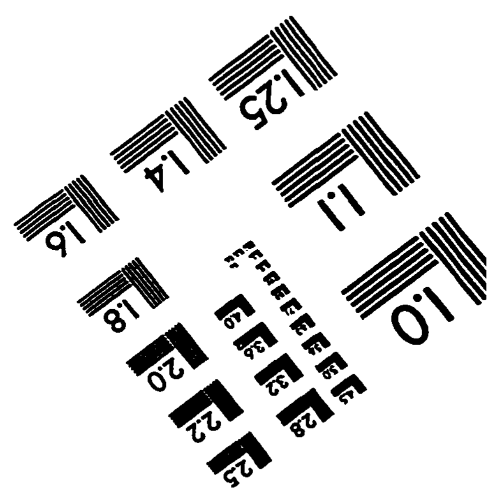

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