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# A QUANTITATIVE ANALYSIS OF THE EFFECTS OF CHESS INSTRUCTION ON THE MATHEMATICS ACHIEVEMENT OF SOUTHERN, RURAL, BLACK SECONDARY STUDENTS

by

James Paul Smith, B. S., B. S., M. Ed.

A Dissertation Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Education

COLLEGE OF EDUCATION LOUISIANA TECH UNIVERSITY AND LOUISIANA EDUCATION CONSORTIUM

May 1998

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EFFECTS OF CHESS INSTRUCTION ON THE MATHEMATICS

ACHIEVEMENT OF SOUTHERN, RURAL, BLACK, SECONDARY STUDENTS

be accepted in partial fulfillment of the requirements for the degree of Doctor of

Education.

tation Research

Head of Department

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Recommendation concurred in: \_ Advisory Committee

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#### ABSTRACT

This study investigates the effects of chess instruction on the mathematics achievement of a group of southern, rural, black, secondary students. Instruments used included the mathematics section of the CAT (Level 20), Group Embedded Figures Test (GEFT), Matrix Analogies Test-Short Form (MAT-SF), Guilford-Zimmerman Spatial Visualization Test (SV), and Guilford Zimmerman Spatial Orientation Test (SO). The treatment group, which received 18 weeks of chess instruction, consisted of 11 females and 8 males. The control group was comprised of 10 females and 10 males. All participants were high school juniors or seniors. Analysis of variance of the pre-tests found no significant differences between the treatment and control groups. Post-test data were analyzed by 2 X 2 MANCOVA which used statistically significant pre-tests as covariates. The treatment group scored significantly higher than the control group on post-test measures of mathematics achievement, F(1, 38) = 4.14, p < .043; field dependence/ independence, F (1,38) = 6.02, p < .019; spatial visualization, F (1, 38) = 14.13, p < .019.001; and nonverbal reasoning,  $\underline{F}(1, 38) = 6.09$ ,  $\underline{p} < .037$ . The control group scored significantly higher on the spatial orientation test, F(1, 38) = 4.22, p < .048. Further analysis by one-way ANCOVA found that only female members of the treatment group scored significantly higher on measures of mathematics

achievement. Factor analysis extracted only one variable from the five instruments used in the study. This variable was labeled "Spatially Based Cogntion" (SBC). One-way ANCOVA of this extracted variable also found that only the treatment group females scored significantly higher than the control group females. No significant difference was found between the treatment group males and control group males for the extracted variable.

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#### CHAPTER 1

#### INTRODUCTION

#### Purpose of the Study

Over the past 35 years there have been numerous studies correlating mathematics achievment and general intelligence to the cognitive style construct of field dependence/independence (FD/I) (Casey, Nuttall, Pezaris, & Benbow, 1995; Cooperman, 1980; Kagan & Zahn, 1975; Mrolsa, Black, & Hardy, 1987; Pearson & Ferguson, 1989; Perney, 1976; Witkin, Dyk, Faterson, Goodenough, & Karp, 1962). FD/I has also been shown to have a significant correlation to spatial ability (MacLeod, Jackson, & Palmer, 1986; Witkin & Goodenough, 1981).

Much of the achievement gap in mathematics between genders and races can be directly attributed to the manner in which individuals perceive their environment, their relationship to their environment, and their ability to mentally manipulate objects (Kagan & Zahn, 1975; Pearson & Ferguson, 1989; Voyer, 1996). It is therefore no surprise that the individuals with the lowest mathematics achievement also demonstrate the greatest degree of field dependence (Forns-Santacana, Amador-Campos, Roig-Lopez, 1993; Kagan & Zahn; Perney, 1976; Voyer).

Although the FD/I construct will be examined thoroughly in Chapter 2, it will nevertheless be helpful to describe briefly the phenomenon. The terms field dependent and field independent are two extreme ends on a continuum that in the extreme are not softened by the influence of the opposing end (Schmeck, 1988). Global has been a word often used to describe individuals that exhibit field dependence, and analytic is used to describe individuals that are classified as field independent. Schmeck described field independent individuals as:

having focused attention, noticing and remembering details. They have an interest in operations and procedures, or the "proper" ways of doing things and prefer step-by-step, sequential organizational schemes. Their thinking, like their attention, is more controlled and consciously directed than that of individuals with a global style. They are gifted at critical and logical thinking. They are also gifted at seeing differences between apparently similar experiences, in contrast to the global thinker, who is gifted at seeing similarities between apparently different experiences. (p. 328)

Rather than being linear or sequential, the field dependent individual's organizational schemes involve more random or multiple accessibility of components, allowing numerous and varied associations between experiences. His/her thinking is more intuitive than that of the analytic person, and emphasis on conscious control of thoughts is less evident (Schmeck, 1988). Field dependent individuals like group work and have demonstrated a preference for academic

subjects and occupations that are people-centered (Chinien & Boutin, 1993). Other aspects of the FD/I construct, such as its use as a measure of personality and its relationships to general intelligence (Satterly, 1979) and mathematics achievement (Mrosla et al., 1987), will be discussed later.

Several studies (Fennema & Sherman, 1977; Pearson & Ferguson, 1989) have confirmed a significant correlation between mathematics achievement and spatial ability. A correlation between chess expertise among children and spatial ability has also been found (Horgan & Morgan, 1989; Van Zyl, 1991). Christiaen (1976) and Van Zyl independently demonstrated that chess instruction significantly improved the mathematics achievement of elementary and middle school students.

Christiaen (1976) conducted his study with 40 10-year-old, white, male, 5th graders in Belgium. Half of the students received 1 hour of chess instruction per week for 15 months. At the end of that time he tested both groups for cognitive development by Piagetian standards and standardized intelligence tests and recorded their school results. The chess group outperformed the non-chess group in all comparisons, but the only statistically significant difference was in school results.

Van Zyl (1991) followed the progress of 160 South African middle school students, 80 chess players and 80 non-chess players, for a 3-year period. Initially, there was no significant difference in the IQ scores of the 2 groups. Compared to the pre-test results, the total IQ scores of the chess playing group were significantly higher than the control group during the post-test. These results, while not proving that chess is the causal agent of the improved IQ scores, certainly deserved some attention.

While Christiaen's (1976) treatment group contained only one rated chess player, Horgan and Morgan (1989) conducted a study with 113 nationally ranked junior players to determine if a relationship existed between spatial ability and chess expertise. Among Horgan and Morgan's hypotheses were: children who excel at chess will measure above average on spatial abilities as measured by Raven's Progressive Matrices, and, for children who excel at chess, chess skill will be highly correlated with spatial abilities. Both hypotheses were confirmed.

DeGroot's (1978) earlier work found that spatial ability did not correlate well with the skill of adult chess players; however, he found a correlation between chess skill in adults and logical thinking ability. It should be noted, though, that the adults used in DeGroot's research were all chess masters or grandmasters and were 32 years of age or older. This suggests an important question: At what age or at what stage of cognitive development do chess players begin to rely more on their logical thinking abilities than on spatial ability? This question has never been properly addressed as no serious quantitative studies have been conducted with high school-aged chess players (D. D. Horgan, personal communication, October 24, 1996). Christiaen (1976) and Van Zyl (1991) demonstrated that mental activities associated with playing chess contributed to higher mathematics achievement among elementary and middle school students. At least one study of middle school students (Rifner, 1992) failed in its attempt to link chess instruction to academic success. However, in Rifner's case, the cognitive task was the analysis of poetry rather than mathematics, and no literature has been found demonstrating a relationship between spatial ability and analysis of poetry.

It may be possible that chess instruction can improve both spatial ability and logical thinking ability among individuals who have not been previously exposed to chess. In turn, these two abilities may increase mathematics achievement. It was this question which this study specifically addressed: Would chess instruction improve the mathematics achievement of southern, rural, black high school students?

#### Justification for the Study

Several researchers have found correlations between FD/I, spatial ability, and mathematics achievement (Cooperman, 1980; MacLeod et al., 1986; Tracy, 1987; Voyer, 1996). They have also found the achievement gap widening between white males and minorities and females, particularly during the high school years (Burnett, Lane, & Dratt, 1979; Kagan & Zahn, 1975; Kush, 1996; Moore & Smith, 1987).

This achievement gap has dramatic effects on individuals' choices of careers, college admission, and eventual employment (Koroluk, 1987). In assessing the scores on mathematics achievement tests of 11,914 men and women aged 15 to 22, Moore and Smith (1987) found significant main effects for sex, education, and ethnic group membership. They went on to state that whites benefited the most from continued education and blacks benefited the least. Even when blacks stayed in school and took more mathematics courses, they did not benefit from the instruction as much as whites.

This achievement gap between genders and ethnic groups may be directly related to FD/I and its effect on spatial ability. Perney (1976) administered Witkin's Embedded Figures Test of FD/I to 40 6th-grade students who had IQ scores between 110 and 120. The students were grouped according to gender and race. There were 10 white males, 10 white females, 10 black males, and 10 black females respectively, in each sub-group. White males showed the greatest field independence, followed by white females, black males, and black females. The degree of FD/I on this test was measured by the length of time required to complete the task. On average, black females (1,928 seconds) required almost twice the time needed by white males (1,031 seconds). Unless methods can be found to enable extremely field-dependent students to tap into field-independent behaviors, many career and educational opportunities will remain closed to them. The government of Venezuela recognized this problem among its citizens and began Project Intelligence in 1980 (Gonzalez, 1990). The purpose of this project was to improve the thinking abilities of Venezuelan high school students. One of the intervention methods used in the project was the introduction of chess into the nation's schools.

Chess was selected on the assumption that playing chess enhances certain intellectual abilities related to abstract thinking, problem solving, and analysis of spatial relationships. It was also assumed that the abilities acquired through playing the game would eventually be transferred to other cognitive areas (Gonzalez, 1990). The pilot project involved 230 children aged 7-9 from varied socioeconomic backgrounds. They were taught chess for 2 years and were given formative assessments throughout that time. According to Gonzalez, the investigators concluded that the statistically significant improvement observed in some mental capacities of the experimental group was due to the chess program. However, this program was discontinued after 1984 due to budget cutbacks.

Having documented the success of chess programs with improving certain mental activities in elementary and middle school students of varied socioeconomic backgrounds, it is a logical extension of this idea to study the effects of chess instruction on high school students. This is particularly important because high school is where the greatest achievement gaps between ethnic groups occur (Moore & Smith, 1987). It is also important to study the effects of chess instruction at this time in the students' academic careers because it becomes much more difficult to alter an individual's cognitive style after the age of 17 (Witkin & Goodenough, 1981).

#### Theoretical Model

The theoretical model for this study is based on the assumption that knowledge and skills acquired in one domain can be transferred to other domains by the individual. However, several studies (Hayes & Simon, 1977; Simon & Hayes, 1976) have failed to show this, even when the problems were similar. In order for knowledge and skills to be transferred, the students must be taught a set of rules, know when to apply them, and receive interactive training and feedback (Palinscar & Brown, 1984; Perkins & Salomon, 1989).

In a study involving 5, 9, 13, and 17-year olds, Siegler (1983) found that children seemed to transfer skills better in situations they knew relatively little about. When these children were given a rule for solving balance beam problems, 5-year-olds outperformed 17-year-olds with 93% correct responses compared to 46%. This was probably due to over-practice in one type of skill and the desire to use that skill, even when not appropriate. It also indicates that when prior knowledge cannot be applied, students are more likely to look for creative solutions. McKeachie (1987) argued that transfer must always occur, because knowledge is never applied under exactly the same conditions as it was learned. This argument is more philosophical than research based. Of the studies (Christiaen, 1976; Christiaen & Verholfstadt, 1978; Horgan, 1987; Rifner, 1992; Van Zyl, 1991) which attempted to use chess instruction to improve academic achievement, only Christiaen described the curriculum used for teaching chess. Rifner listed a set of chess abilities he wanted his subjects to master, but did not describe the curriculum used to achieve those outcomes. Many studies (DeGroot, 1978; Frydman & Lynn, 1992; Horgan & Morgan, 1989; Van Zyl) sought participants that had already achieved some degree of chess expertise and by virtue of that expertise they may have already reached their maximum level of spatial ability or logical thinking ability. That expertise could have biased those studies even before they had begun.

The subjects involved in this study had very little or no previous knowledge of the game of chess. The instruction they received was based on the curriculum developed by Pelts and Alburt (1992), which emphasizes spatial visualization, visual imagery, critical thinking, and problem solving. This study should provide more insight into how chess instruction effects cognition because the perspective from which the subjects approach the game of chess was controlled from the onset. By emphasizing the spatial aspects of chess directly, the subjects should have been better able to apply these newly learned skills to mathematics. There is no way of knowing if this method was attempted in previous studies, since very little description of the curriculum has been provided. Christiaen (1976) delivered 42 hours of instruction over a 15-month period. This study was designed to provide approximately 100 hours of instruction over a semester.

By teaching chess with a curriculum which emphasized visualization, critical thinking and problem solving, subjects were provided three of the four conditions needed for knowledge transfer to occur: a set of rules, interactive training, and feedback (Palinscar & Brown, 1984; Perkins & Salomon, 1989). The fourth condition, knowing when to apply the rules, could only be met by directly teaching specific links between chess and mathematics. Such instruction would have biased the study. Therefore, it was left up to the students to determine when to apply their newly acquired skills.

#### Limitations of the Study

Generalizations from this quasi-experimental study are limited because all subjects in this study were African-American. The study was also limited because all participants were aged 16-17. A third limitation to this study was that chess instruction was taught by the researcher. However, Christiaen (1976) and Rifner (1992) also taught the chess class in their studies because a suitable instructor could not be found.

A fourth limitation was the small number of participants. There were 19 subjects in the treatment group (11 females and 8 males) and 20 in the control group (10 females and 10 males). Christiaen (1976) used treatment and control

groups consisting of 20 members each. Rifner's (1992) study was limited to 8 subjects in the treatment group and 5 in the control group.

A fifth limitation was that members of both the treatment and control groups could not be restricted or controlled in their choices of mathematics instruction. They were free to enroll in any of the advanced mathematics courses offered in the school or they could choose not to enroll in any mathematics class if they had fulfilled the state mathematics requirement for graduation.

#### Research Hypotheses

The following hypotheses were investigated in this study. They are written in the null form.

Hypothesis 1:

Chess instruction will have no effect on the mathematics achievement of the treatment group.

#### Hypothesis 2:

Chess instruction will have no effect on the degree of FD/I of the treatment group.

#### Hypothesis 3:

Chess instruction will have no effect on the spatial ability of the treatment group.

#### Hypothesis 4:

Chess instruction will have no effect on the nonverbal reasoning ability of the treatment group.

#### Definitions

- Analogical methods: Transferring the knowledge and experience used in solving one problem (source problem) to another problem (target problem) by using a mapping process.
- 2. Critical thinking skills: The ability to transfer the knowledge and skills used to solve a problem in one content area to an application in another content area.
- 3. Field dependence: A description of a mode of perception in which the individual focuses on the entire perceptual field and has difficulty in distinguishing its constituent parts. Individuals who score 1 to 6 in the Group Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971) are considered field dependent.
- 4. Field independence: A description of a mode of perception in which the individual is able to focus on particular parts of the perceptual field and is able to withdraw them from their context for closer examination. Individuals scoring 13 to 18 on the Group Embedded Figures Test (Witkin et al., 1971) are considered to be field independent.
- 5. Mathematics achievement: For purposes of this study, mathematics achievement was defined as an individual's score on the numerical calculation

and mathematical application sections of the California Achievement Test (Level 20).

- 6. Metacognition: The knowledge and control individuals have over their own thinking and learning activities.
- 7. Spatial ability: The measure of an individual's success at performing tasks which require mental rotation and correctly describing one's orientation in relation to an object after the perspective has been changed.

#### **CHAPTER 2**

#### **REVIEW OF LITERATURE**

#### Introduction

The existence of a metacognitive link between participation in chess instruction programs and mathematics achievement has been demonstrated in studies with elementary and middle school students (Christiaen, 1976; Christiaen & Verholfstadt, 1978; Horgan, 1987, Van Zyl, 1991). However, no studies of the effects of chess instruction on mathematics achievement have been conducted at the secondary level (D. D. Horgan, personal communication, October 24, 1996).

In order to postulate the existence of a metacognitive link between the skills required for mathematics achievement and those required for chess expertise of students at the secondary level, it was first necessary to examine the nature and essence of the measurable cognitive abilities which influence both. These measurable factors are cognitive style, as defined by the field dependence/ independence construct (Gallagher, 1989; Goodenough & Karp, 1961; Griffin & Franklin, 1996; McKenna, 1984), spatial ability (Frydman & Lynn, 1992; Horgan & Morgan, 1989; Van Zyl, 1991; Voyer, 1996), and logical reasoning ability (Cooperman, 1980; DeGroot, 1978).

#### Field Dependence-Independence (FD/I)

#### Defining FD/I

FD/I, also known as psychological differentiation, is a psychological construct generally related to the work of Witkin et al. (1962). During World War II, Witkin observed that some fighter pilots, when flying long distances in thick clouds or fog, could maintain their orientation and reference to the horizontal, while others became disoriented when they lost sight of the horizon (Chinien & Boutin, 1993). Witkin designed and conducted a series of laboratory experiments to investigate this phenomenon.

The task in Witkin's original experiments was to have the subject correctly perceive an upright position (Witkin & Goodenough, 1981). Perceiving which direction is upright is ordinarily determined by two sets of experiences working in tandem. These are the visual field around us, which usually has a framework of reference such as walls or some other type of main axis, and the direction of gravity as perceived by the subject's tactile and kinesthetic senses (Witkin & Goodenough). The vertical direction is the same whether determined by referring to the visual background or by sensing the pull of gravity, and the subject should have the same outcome regardless of the frame of reference used.

Three tests were used to separate and determine the frame of reference used by the test subjects. These were the body-adjustment test (BAT), the rod and frame test (RFT), and the rotating room test (RRT) (Witkin & Goodenough, 1981). In the BAT, the subject was seated in a small tilted room that could be displaced clockwise or counter-clockwise. Likewise, the subject's chair could also be tilted by the experimenter independently of the room. When given the task of adjusting the chair (and therefore his own body) from an initially tilted position to the upright, with the surrounding room in a tilted position, some subjects aligned the body with the tilted room, believing themselves to be sitting perfectly straight. These subjects were clearly using the room as their frame of reference. Subjects who used their perception of gravity acting on their body as their frame of reference were able to correctly align themselves in an upright position (Witkin & Goodenough).

The RFT was conducted in a totally darkened room in which the subject viewed a tilted, luminous, square frame which contained in its center a luminous, pivoting rod. The subject was asked to determine when the rod was in the vertical position against the background of a tilted frame. Results varied greatly depending on whether the subject used the frame or his own body as the frame of reference (Witkin & Goodenough, 1981).

The RRT was similar to the BAT with the exception that the room was rotated on a circular track and thus creating a centrifugal force which negated the effects of gravity on the body. Again the results varied greatly depending on which frame of reference the subject used (Witkin & Goodenough, 1981). When comparing results, it was found that subjects were consistent in their use of the visual field or their body as the frame of reference during each of the three tests. The concept that subjects used either an external visual field or an internal body perception to determine upright led to the designations "field dependent" to describe a subject that used an external frame of reference and "field independent" to describe a subject that used an internal frame of reference, and the terms were intended only to describe the preferred frame of reference in orientation tasks (Witkin & Goodenough, 1981).

The realization that subjects in these studies were being required mentally to remove (disembed) an item from an organized complex field led researchers to search for other methods by which the subjects could demonstrate their ability to separate a simple design from a complex design. This led to the development of a paper and pencil test to measure FD/I, the Embedded Figures Test by Witkin, Oltman, Raskin, and Karp (Witkin & Goodenough, 1981), which was eventually able to replace the RFT, BAT, and RRT laboratory tests.

#### FD/I as a Cognitive Style

Theories of cognitive styles fall into three major categories according to Grigorenko and Sternberg (1995). These three approaches are cognition centered, personality centered, and activity centered. FD/I is best classified as cognition centered, because the criteria for determining it are measured by tests with right and

wrong answers and the FD/I styles themselves bear a close resemblance to mental abilities and are measured quantitatively rather than qualitatively.

Studies of the ability to separate a simple design from a more complicated field led to further research dealing with analytical problem solving. Subjects identified as field dependent in perception of the upright were found to have greater difficulty in solving problems which required them to take critical elements of the problem out of the context in which they were presented and restructure them (Witkin & Goodenough, 1981). This discovery, linking the FD/I construct to the ability to overcome embedding contexts in problem solving tasks, broadened the concept from a perceptual ability used to determine the upright direction to one which included cognitive ability (Witkin et al., 1962). Witkin, Moore, Goodenough, and Cox (1977) also found that a relatively field-independent person was likely to overcome the organization of the field or to restructure it when presented with a field having a dominant organization, whereas a relatively fielddependent person tended to adhere to the field as given. This characteristic difference in the manner of approaching the field also showed itself under circumstances where the field lacked inherent organization, according to Nebelkopf and Dreyer (1970). Moore, Gleser, and Warm (1970) found that relatively fieldindependent individuals frequently imposed structure spontaneously to material which lacked structure.

Because cognitive style represents a learner's preferred mode of perceiving and processing information, understanding how it functions in the individual is of paramount importance to educational psychologists and curriculum designers. Students may encounter tasks that by the nature of their cognitive structure require individuals to process information in a manner incongruent with their perceptual or cognitive style. The solution to this problem is to present the information in a form that students can process or to train students to adapt their processing skills to accommodate for the incongruent teaching style. Witkin, Goodenough, and Karp (1967) found that as individuals mature, movement toward greater field independence can occur, but this movement slows considerably by age 17 and all but ceases after 24 (Karp, 1963). Altering cognitive style will be discussed in another subsection.

#### FD/I and Intelligence

Several studies have linked performance on tests of FD/I to general intelligence (Cooperman, 1980; Goodenough & Karp, 1961; Mrolsa et al., 1987; Satterly, 1979). Griffin and Franklin (1996) conducted a study of undergraduate college students and concluded that measures of FD/I can be used to predict college performance. McKenna (1984) stated that field independence should be classified as a cognitive ability rather than as a cognitive style because of its significant correlation to spatial ability. Early work in the field of FD/I (Witkin et al., 1962) suggested that some intellectual tasks required the capacity for overcoming embedding contexts. This led to the logical conclusion that field independent individuals should surpass field dependent individuals in tasks that required multiple step solutions or analytical problem solving skills. This has certainly been shown to be the case (Cooperman, 1980; Mrolsa et al., 1987; Satterly, 1979).

Satterly (1979) tested 430 pupils aged 10-11 to determine FD/I and their level of achievement in mathematics, geography, and English. Statistical analysis of these results showed a small but significant correlation between measures of FD/I and IQ.

Cooperman (1980) tested a sample of 412 undergraduate college students for FD/I and administered a rote learning task and a verbal reasoning task. These tasks were chosen because of their lack of resemblance to items on Wechsler's Test of IQ that could be directly linked to spatial ability. The field-independent groups tested significantly higher on both the rote learning and verbal reasoning tasks. Mrolsa et al. (1987) reached the same conclusion when correlating scores in the Group Embedded Figures Test (GEFT) to the mathematics achievement scores of 44 students in a traditional high school in a midwestern metropolitan area.

Griffin and Franklin (1996) administered the GEFT to 143 college freshmen enrolled in a course entitled "Psychological Foundations of Education" and compared the results to their GEFT and ACT scores obtained from university
records. Students' GEFT scores were correlated to ACT scores,  $\underline{F}(1, 141) = .29$ ,  $\underline{p} < .01$ . Field-independent students also scored significantly higher on criterion referenced tests given during the course. Regardless of the mechanism responsible, field-independent students consistently scored higher on tests of intelligence than did field-dependent students.

### FD/I as a Measure of Personality

Results on tests of FD/I are related to many characteristics that fall under the broad umbrella of psychological differentiation. These characteristics are not end products of development in separate channels but are diverse expressions of an underlying process of development toward greater psychological complexity according to Witkin et al. (1971). The GEFT has proven very reliable in the assessment of preferred mode of perception, r = 0.82 (Witkin et al.). Due to the high correlation between perception and personality, many psychologists (Caliste, 1985; Witkin, et al.) consider the GEFT as much a test of personality as cognitive style.

Research has indicated that field-dependent individuals are drawn to people, tend to be alert to social cues, and generally have highly developed interpersonal skills (Caliste, 1985). They like to work with groups and prefer academic subjects and occupations that are people centered. Witkin and Goodenough (1981) hypothesized that this interpersonal orientation is likely an adaptive behavior designed to give field-dependent individuals access to information that may help them structure ambiguous situations, something they are not easily able to do on their own. As a result, field-dependent individuals tend to be described as warm, affectionate, tactful, accommodating, and accepting of others, not likely to express hostility directly against others when such feelings are aroused in an interpersonal context (Witkin & Goodenough, 1977).

Field-independent individuals are more impersonal, less alert to social cues and have less developed interpersonal skills than field-dependent individuals. They tend to be aloof, theoretical and not sensitive to others. They also like to work alone and prefer occupations in which human interaction is less important. They are analytical in their approach to problem solving and learn abstract or theoretical material with relative ease. They are also known for rapid problem solving ability (Witkin & Moore, 1974). Some studies (Witkin & Goodenough, 1977) have gone so far as to describe field-independent individuals as demanding, inconsiderate, manipulative of others as a means of achieving personal goals, and cold and distant in relations with others. Very little is known about the dynamics of social skills of field-independent individuals beyond the evidence that they are limited in interpersonal competencies. It has been speculated that their social skills are likely applications of their restructuring skills to the social domain, rather than investment in relations with others (Witkin & Goodenough, 1981).

Crutchfield, Woodworth, and Albrecht's study (as cited in Witkin et al., 1977) found that relatively field-dependent army officers performed significantly better than field-independent army officers in recognizing other officers with whom they had previously spent several days at an assessment center. Adcock and Webberley (1971) found that when field-dependent and field-independent individuals were given the intentional task of learning and identifying faces, the field-independent individuals were significantly superior. The implication of these studies is that while field-independent individuals may have better skills for intentional learning and recall, field-dependent individuals show superior recall from social situations (Witkin, et al.).

# The Effects of Culture and Child Rearing Practices on FD/1

Many studies (Figueroa. 1980; Forns-Santacana et al., 1993; Huntsinger & Jose, 1995; Kagan & Zahn, 1975; Laosa, 1980; Perney, 1976; Saracho, 1991; Strom, Johnson, Strom, & Strom, 1990) have been conducted during the past 20 years in an attempt to define better the roles of culture and child rearing practices in the development of cognitive style. Most of these studies have focused on minority groups and females because of the higher incidence of field dependence among these segments of the population. However, some studies (Buriel, 1975; Saracho) have tried to refute that generalization. Early investigations into the cultural effects of FD/I focused on race and gender. Perney (1976) demonstrated significant differences in FD/I along racial and gender lines in a study of 40 suburban 6th graders, all with IQ measures between 110 and 120. The subjects consisted of 20 whites and 20 blacks with 10 males and 10 females in each racial group. The degree of FD/I was determined by the mean time, in seconds, required for each group to complete an embedded figures test.

A 2 X 2 factorial analysis showed that the main effects for race and gender were both significant. The mean times, in seconds, for the four groups were 1,031 for white males; 1,129 for white females; 1,156 for black males; and 1,928 for black females. The most startling result was the mean time of black females. Perney (1976) speculated that peer pressure among black females that encouraged conformity and thereby strong dependence on external referents might have been responsible for their extreme degree of field dependence. However, that hypothesis could neither be proven in this case nor generalized to black females in other communities.

Figueroa (1980) conducted a similar study but used the RFT rather than a pen and pencil test to measure FD/I. The subjects were 32 Mexican-Americans, 32 Central and South Americans, 32 African-Americans, and 32 Anglo-Americans, equally divided by gender. All subjects in the study, ages 14 to 17, were enrolled in Title 1 mathematics and reading programs in a northern California school district. All the Hispanic subjects were either born outside the United States or had at least

one parent who was born outside the United States. All of the African-American and Anglo-American subjects were native-born Americans.

The group means in order of increasing field dependence were Anglo-American, Mexican-American, Central and South American, and African-American. Confidence intervals for the difference between each pair of ethnic group means were significant (g < .05) for every comparison that included the African-American ethnic group. Within each ethnic group, test results of females indicated greater field dependence than males. The differences in the mean scores between males and females were significant for Anglos at the .05 level and for African-Americans at the .025 level. The Central and South American group and the Mexican-American group means showed this trend, but the differences were not statistically significant (Figueroa, 1980). Consistent with Perney (1976), African-American females showed the greatest field dependence among all the groups represented.

Forns-Santacana et al. (1993) examined the effects of socioeconomic status in a study involving 79 subjects of low socioeconomic status (50 girls and 29 boys) and 38 subjects of upper-middle socioeconomic status (20 girls and 18 boys) enrolled in 2nd grade near Barcelona, Spain. In addition to testing for FD/I, the researchers also evaluated subjects for verbal, perceptual, quantitative, memory, and motor skills. In addition to confirming other studies that found links between FD/I and over-all academic performance, a significant difference in the mean scores between low socioeconomic and upper-middle socioeconomic groups was found at the .04 level.

One of the more insightful studies on the influence of culture on child development was conducted by Strom et al. (1990). The subjects in this study, 69 rural Hispanic (first and second generation) and Anglo parents and their 4-to-8year-old children who had been identified as potentially gifted, were tested and observed during a 5-week summer program. The parents were assessed with the Parent as a Teacher Inventory (PAAT) in their preferred language.

This instrument provided the researchers with data describing the parents' desires and expectations of their children, their ways of interacting with their children, and the actions they take in response to certain child behaviors. Other domains of child development examined by the PAAT were parental support for creativity, parental frustrations with lack of success by a child, parental control of the learning situation, parental understanding of play as an intellectual activity, and the parents' evaluation of their ability to facilitate their child's intellectual development (Strom et al., 1990). In addition to completing a survey instrument, parents and children were brought to school where they could be observed interacting during intellectual activities.

Researchers found that Anglo parents were more inclined to support their child's creative development by encouraging imagination, guessing, and arranging for solitary play. Hispanic parents considered it unacceptable when their children

mentioned imaginary friends. Both groups encouraged their children to ask questions, engage in pretending, and experiment with problem solving. Hispanic parents punished their children more often for learning failures, while Anglo parents were more aware of the potential for learning during play and provided more mental stimulation. Hispanic parents were also more likely to become actively engaged with the children during play, while Anglo parents supported long periods of solitary play (Strom et al., 1990).

The research by Strom et al. (1990) indicated cultural behaviors in the Hispanic community tend to develop more field-dependent characteristics, while parental behaviors in the Anglo culture tend to foster field independence. Saracho (1991) stated that such conclusions were the result of an oversimplified view of Hispanic culture and argued that when viewed in its entirety, Hispanic culture produces a balance between cognitive styles. This is supported by Mendoza's (1994) claim that fourth and fifth generation Hispanics identified more with predominant American culture than first and second generation Hispanics.

Contrary to claims by Saracho (1991) and Mendoza (1994), Inclan and Hernandez (1992) contended that the greater field dependence of Mexican-American children may reflect traditional socialization practices that stress adherence to convention and a continued identity with the family. According to Ramirez and Price-Williams (1976), Mexican-American children were more cooperatively motivated than Anglo children and the emphasis on social integrative

values taught in the home often produced a pro-social orientation that was consistent with increased attention to social cues in learning situations, which is characteristic of field-dependent style.

# The Stability of FD/I Over Time

Witkin et al. (1967) found FD/I to be stable over time. Witkin et al. were able to test and chart the psychological differentiation of more than 400 subjects over a period of 13 years. Group ages of participants initially were 8, 10, 11, 12, 13, 15, 17 and a group of college students whose mean ages at the beginning of the study were 21.2 for males and 19.6 for females. Each age group initially contained 25 males and 25 females, with the exception of the 10-year-old group and college group, which contained more members. As many members of each age group as could be tracked over the 13-year period were tested every 3 years until the girls reached 17 and the boys reached 24.

Three tests of FD/I were used: the Rod and Frame Test (RFT), the Body Adjustment Test (BAT), and the Embedded Figures Test (EFT). Definite patterns of development began to emerge for each test when the data were graphed. Males were more field independent than females on each of the three tests at all ages, except 11 and 13 on the BAT. Females reached their most field-independent condition at age 13 on the BAT, after which point they had a slight tendency back

toward field dependence. Males' field independence on the BAT peaked at 17 and moved slightly toward field dependence afterward.

According to Witkin et al. (1967), males showed greater field independence than females at all ages on both the RFT and EFT. Females peaked in field independence on the RFT at 15 and then moved slightly toward greater field dependence, while males reached their greatest field independence scores at 17 and then moved toward field dependence at a much slower rate than females. Both genders peaked in their field independence scores at 15 on the EFT, but while females moved toward field dependence as they matured, males' scores leveled off. Because Witkin et al. did not include any other demographic information about the subjects in this study other than age and gender, it is impossible to draw any conclusions concerning cultural or socioeconomic influences.

# Spatial Ability

### Defining Spatial Ability

Spatial sense as defined by the National Council of Teachers of Mathematics is an intuitive feel for one's surroundings and objects in them (Del Grande, 1990). This sense is referred to more specifically in psychological literature as the skill represented by transforming, generating, and recalling symbolic, nonlinguistic information (Linn & Petersen, 1985). Three categories of spatial ability frequently used in factor analysis by psychometricians are spatial perception or spatial orientation, mental rotation, and spatial visualization (Linn & Petersen, 1985). The origin of these categories was derived from the task specific tests used to measure spatial ability.

# Spatial Perception

Tests of spatial perception generally require subjects to determine spatial relationships with respect to the orientation of their own bodies, in spite of distracting information. In performing tests of this type the subject must choose between using visual information as their frame of orientation or using kinesthetic information provided by their body's perception of gravity. The RFT developed by Witkin et al. (1962) is the classic example of this type of test. This test also requires the subject to ignore certain sensory inputs in an effort to disembed the correct information that will provide the answer to the correct orientation.

## Mental Rotation

Tests of mental rotation measure the amount of time required for a subject to rotate a two- or three-dimensional figure mentally and determine a correct solution to a problem. Time is used as the criterion for determining results because accuracy of finding solutions is normally extremely high (Linn & Petersen, 1985). Controversy exists as to what type of mental process is used in rotating figures.

Shepherd and Cooper (1982) found evidence linking the ability to analytical processing strategies rather than a process analogous to physical rotation.

Although tests of mental rotation were used in original research investigations of over-all spatial ability, Fruchter (1954, as cited in Linn & Petersen, 1985) and Smith (1964, as cited in Linn & Petersen) found that the two major factors characterizing spatial ability were spatial perception or orientation and spatial visualization.

Wilson and Vandenberg (1978) factor analyzed a group of 15 cognitive tests and found a similar spatial factor structure for different ethnic groups, different age groups, and genders. In all cases this spatial factor was identified with a mental rotation test, thus making the case that mental rotation is an ability distinct from spatial perception or spatial visualization. Interestingly, it is this component of spatial ability that best correlates to the gender differences in mathematics achievement. Pearson and Ferguson (1989) found that spatial perception and spatial visualization contributed only 0.5% and 1% respectively to the variance of mathematics achievment scores attributable to gender, while mental rotation accounted for 12% of the variance.

## Spatial Visualization

Spatial ability tasks involving complicated, multi-step manipulations of spatially presented information are generally categorized as spatial visualization

(Linn & Petersen, 1985). Although these tasks may involve the use of spatial orientation or mental rotation, they are distinguished from either of these skills by the possibility of multiple solution strategies. Measures of this ability include the Hidden Figures Test, by Witkin et al. (1971), the Differential Aptitude Test (spatial relations subtest), and the Guilford-Zimmerman Spatial Visualization Test. These tests stress the ability to use a repertoire of strategies, flexibility of selecting strategies, and keeping track of multistep operations and speed (Linn & Petersen).

Burnett et al. (1979) found a significant positive correlation between scores on the Guilford-Zimmerman Visualization Test and mathematical ability as measured by the Quantitative Scholastic Aptitude Test. Their study involved 183 male and 81 female undergraduate students. When visualization was controlled for in the statistical analysis, there was less than 1% difference in the mathematics achievement between the sexes.

These individual components of spatial ability are acquired and developed by use as the child matures from infancy to adolescence, but their continued refinement is believed to be impaired by the onset of puberty (Newcombe & Bandura, 1983). Researchers (Newcombe & Bandura; Waber, 1977a, 1977b) believe this impairment of cognitive development brought on by the onset of puberty accounts for the superior performance by males over females in tests of spatial ability because females generally reach puberty approximately 2 years sooner than males. Waber (1977a) has suggested that the hormonal increases associated with the onset of puberty affect the development of hemispheric lateralization, which in turn may affect cognitive restructuring ability.

In a study of 85 6th-grade Caucasian girls, Newcombe and Bandura (1983) found a significant relationship between spatial ability and age at the onset of puberty. The study also showed that personality traits and intellectual interests were linked to spatial ability. This study clearly tied the timing of the cessation of the development of spatial ability to the onset of puberty. Earlier maturing girls were likely to have more feminine personality traits and were less likely to participate in activities which required spatial ability than girls who matured later (Newcombe & Bandura). This could help explain the extreme field-dependent behaviors exhibited by African-American females on tests of FD/I because they typically reach puberty sooner than Caucasian females (Rushton, 1988).

### **Spatial Ability and Mathematics**

In a meta-analysis of 100 studies of mathematics performance and gender differences, Hyde, Fennema, and Lamon (1990) found that females outperformed males by a negligible amount among elementary school students and in the general population. However, males began to excel in mathematics at the ages 12-13 and the difference in problem solving ability continued increasing as the selective samples became smaller, due to specialized mathematics applications needed for higher cognitive tasks. These findings tend to coincide with results of the study by Newcombe and Bandura (1983) concerning the onset of puberty in females.

In analyzing the SAT mathematics scores and English scores of 760 diverse college bound subjects with their scores on three tests of spatial ability Casey et al. (1995) found that males outperformed females in mental rotation and mathematics, except in the low-ability group. Males' scores in mathematics correlated well with scores of mental rotation ( $\rho = 0.54$  for males and  $\rho = 0.38$  for females). Males' advantages in mathematics were reduced to nonsignificant levels when mental rotation ability was covaried out of the statistical analysis. However, when mathematics scores were covaried out of the mental rotation scores, the differences were still significant in favor of males among the high ability groups.

In most studies of mathematics achievement and spatial ability, the mathematics component was derived from scores on standardized mathematics achievement tests, but Voyer (1996) pointed out that gender differences in performance in mathematics classes tend to favor girls. It appears that results on mathematics achievement tests and class grades in mathematics courses may represent different aspects of mathematical knowledge. It has also been postulated that course grades may involve a social dimension not found in paper and pencil tests of achievement (Voyer).

One explanation of male superiority on tests of spatial ability was offered by Tracy (1987) following a meta-analysis of several unrelated studies involving children's toys, spatial ability, and mathematics and science achievement. Although no causal mechanism has been statistically identified, Tracy hypothesized a link between playing with certain types of toys and improved spatial ability, which in turn would effect mathematics and science achievement.

### Summary of Spatial Ability

Numerous studies (Casey et al., 1995; Fennema & Sherman, 1990; Hyde et al., 1977; Pearson & Ferguson, 1989;Voyer, 1996) have reported a significant positive correlation between spatial ability and mathematics achievement for males. These same studies consistently show that average and high ability males 12-13 years of age and older score significantly higher on tests of mathematics achievement than their female counterparts. Whether the gender differences in spatial ability and mathematics achievement are the results of childhood toy selection (Tracy, 1987) or are the product of biological constructs (Newcombe & Bandura, 1983; Waber, 1977a, 1977b), they have been reported consistently by both psychological and biological researchers.

### Critical Thinking Skills

According to Braden (1995), critical thinking skills programs are among the more recent attempts to improve cognitive skills through specific curriculum design. This is most often accomplished through teaching cognitive operations that can be applied over a wide range of content areas. Despite the wider use of such

programs in recent years to improve cognitive skills, critical thinking skills programs have not enjoyed the refinement and popular acceptance of content-based curricula (Bangert-Drowns & Bankert, 1990).

Critical thinking programs most often focus on problem solving techniques that have applications in more than one academic area. The knowledge to solve one problem can be transferred to another by either logical or analogical methods. Application of logical methods involves deductive reasoning in which the student proceeds from one step to the next, supplying proofs or reasons as he or she proceeds until the conclusion or answer is reached.

In analogical problem solving, the knowledge of a source problem is transferred to a target problem by a mapping process in which the learner recalls a relevant problem from memory and applies the methods used in its solution to the new problem (Hsu & Wedman, 1994). The student's ability to accomplish this task is strongly related to content emphasis, instructional factors, practice, and cognitive style.

Gick (1986) found that students who learn to solve problems analogically were able to apply this ability to later tasks. However, this was not always the case because students often did not recognize the relationship between the source and target problems (Gick & Holyoak, 1983).

According to Holyoak (1984), three steps are involved in analogical problem solving. First, the student must access his or her memory and recall a source problem that will be useful in making the analog. Secondly, he or she must adapt the analogy of the source problem to the target problem by making a mental map. Step three involves restructuring the useful commonalities of both problems to provide a framework for the solution. Step three also requires that the learner be able to disembed relevant facts and details from the data given for both problems, and the ability to solve problems via this method is obviously tied to the FD/I construct. Ronning, McCurdy, and Ballinger (1984) reported that FD/I was one of the important indicators of problem solving ability. This may explain the strong statistical link between FD/I and mathematics achievement, particularly in the area of problem solving (Cooperman, 1980; Mrosla et al., 1987; Satterly, 1979).

### <u>Chess</u>

Chess is a board game that is well known throughout the world. It combines several of the skills used in mathematical problem solving, particularly spatial ability (Horgan & Morgan, 1989; Van Zyl, 1991) and logical or critical thinking ability (DeGroot, 1978; Holding, 1985). Chess was chosen as the vehicle to stimulate mathematical achievement in this study for two reasons. First, it utilizes both spatial and cognitive abilities, and secondly, it appeals to children and adults both intellectually and as a source of entertainment.

While mathematical achievement can be measured with a standardized test, no such method exists for chess. The best determinant of chess skill is competition

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against rated players. A method of rating players, known as the Elo rating system, has been in place for years (Holding, 1985). Players either gain or lose points based on their wins, losses, and draws in games against rated players.

A great deal of research has been conducted to determine the exact source of chess expertise (Chase & Simon, 1973; DeGroot, 1978; Holding, 1985; Simon & Chase, 1973) without much success. Most of the research gathered is not generalizable because of the peculiarities of the subjects under study. DeGroot found that chess expertise among his subjects, all adults, was most closely related to logical thinking ability. This was determined by setting up chess problems and asking groups of experts and novices to determine the best sets of moves under the given circumstances. It was found that novices could predict many moves ahead just as well as masters. The difference between master and novice performance was in their final judgment of which particular move was the strongest (DeGroot). In this part of the task, masters vastly outperformed novices.

Chess is also similar to mathematics in that perceptual patterns develop on the board that require particular methods to solve. In this way chess problems can be classified according to type, and the chess player can rely on experience or deductive thinking to find a solution. It is in the recognition of these patterns and the methods used to solve previous problems that any hope of a transfer of skills lies. In addition to the reported benefits of chess instruction on academic performance (Christiaen, 1976), many other claims, best described as affective, have also been made. Van Zyl (1991) argued that students who play chess have greater reasoning ability, more intense concentration, greater task perseverance, better sequencing skills, and greater attention spans. Horgan (1987) stated that chess has been used to help children think clearly and with discipline.

In 1986, Faneuil Adams, Jr., an executive with Mobil Oil, began teaching chess to children in the lowest income areas of New York City. Students quickly learned to play the game and became very skillful (Chess in the Schools, 1997). Teachers reported improved behavior, attitude, and scholastic performance. IBM Corporation funded a study in 1991 to determine the effects of chess instruction in Community School District 9 in New York City. After 1 year, the students participating in the Chess-in-the-Schools Program showed an average gain of 5.37 percentile points against the national average (Chess in the Schools). These results are certainly intriguing, even if the method by which chess instruction improves academic performance is not fully understood.

# CHAPTER 3

### METHODOLOGY

This chapter describes the research design, subject selection criteria, instruments used to assess the dependent variables, experimental procedure, measures that were taken to protect internal validity, results of an earlier pilot study, and statistical protocols that were used to analyze data.

### Research Design

This quasi-experimental study was based on the nonequivalent control group design (Campbell & Stanley, 1963). This design was necessary because the treatment group consisted of members of a pre-existing class and the control group was comprised of volunteers at the same grade level from the general student population of the school. Under these circumstances, pre-experimental sampling equivalence could not be guaranteed (Campbell & Stanley).

The following research hypotheses were addressed in this study.

Ho1: Chess instruction will have no effect on the mathematics achievement of the treatment group.

Ho2: Chess instruction will have no effect on the degree of Field Dependence/Independence of the treatment group.

Ho3: Chess instruction will have no effect on the level of spatial ability of the treatment group.

Ho4: Chess instruction will have no effect on the nonverbal reasoning ability of the treatment group.

### Subject Selection Criteria

The subjects in this study consisted of 39 students, ages 16 and 17, in a southern, rural, high school. All were volunteer participants. The treatment group consisted of 19 students who had enrolled in a humanities class. The control group was comprised of 10 female and 10 male students from the general population in the high school. Because enrollment in the humanities class was open to all juniors and seniors in the high school, control of gender and academic achievement levels of the subjects was not possible.

Christiaen (1976) encountered a similar problem in finding access to treatment and control groups for his study. He eventually obtained access to a class of 40 male middle school students (5th grade). He randomly divided the class and taught 20 students 42 1-hour chess lessons in an after school program over a 15month period.

Rifner (1992) also sought middle school volunteers but had even greater difficulty obtaining subjects. Rather than giving instruction after school, he taught his chess class during a study hall. After having four students withdraw for various reasons, his study was eventually limited to 8 subjects receiving the treatment and a control group of 5 individuals.

The control group in this study consisted of 20 junior and senior volunteers from the general student population. Members of the control group were not enrolled in the humanities class and chose another elective class in the school outside the control of the researcher. Also, members of the treatment and control groups were enrolled in different mathematics courses based on personal choices or academic sequencing of mathematics courses, both of which were beyond the researcher's control.

All participants in the study were of African-American descent. Blacks were selected as the subjects of this study because they have historically demonstrated the greatest degree of field-dependence of all ethnic groups (Perney, 1976). All participants in the study and their parents signed consent forms approved by the Human Subjects Committee before being allowed to participate. (See Appendix B)

### Instrumentation

The instruments used in this study were selected because of their high validity and reliability. The mathematics section of the California Achievement Test (Level 20) was used as the pre- and post-test for mathematics achievement (see Appendix C). This test has been used for decades to measure mathematics achievement in the United States and has an established reliability of 0.88 (CTB-MacMillan/McGraw-Hill, 1992).

Spatial orientation was measured using the Guilford-Zimmerman Test of Spatial Orientation (see Appendix D). This test has been widely used for more than 35 years and measures the individual's ability to relate himself or herself correctly to objects in the environment. It has reliability coefficients of 0.89 and 0.88 for males and females, respectively (Guilford & Zimmerman, 1981).

Spatial visualization was measured with the Guilford-Zimmerman Test of Spatial Visualization (see Appendix E.) This test measures the subject's capacity to manipulate images visually. It also has high reliability coefficients, 0.94 for males and 0.93 for females (Guilford & Zimmerman, 1981).

FD/I was measured using the Group Embedded Figures Test (Witkin et al., 1971). The GEFT (see Appendix F) has high reliability (0.82) and high validity when compared to the Embedded Figures Test (0.82 for males, 0.63 for females).

Nonverbal reasoning ability was measured using the Matrix Analogies Test-Short Form (Naglieri, 1996). This test (see Appendix G) is often used to determine giftedness among subjects who use English as a second language. The test, retest correlation is high (0.78) for the Matrix Analogies Test-Short Form .It was normed with over 100,000 participants (Naglieri).

A method for numerically determining chess strength was necessary to complete some of the planned statistical analyses. For this purpose the Harkness System (see Table 1), a method employed by the United States Chess Federation to rate the playing strength of its members, was used (USCF, 1997). This system is based on adding or deducting points from players' established ratings, while taking into account the difference of their ratings at the time of play and whether the higher rated or lower rated player wins the game. Records of games played between the subjects in the study were kept and rating points awarded beginning 6 weeks after instruction was initiated. That allowed sufficient time for students to develop some proficiency at the game. Each subject was given an initial rating of 1,000 points. Points were then added or deducted based on the results of play according to the Harkness System.

### Procedure

After permanent rosters for classes were generated in late August, consent forms were given to the subjects and their parents. The study began with administration of the pre-tests after the consent forms were returned. Tests were administered by the school counselor over a 4-day period. Approximate time for testing was 50 minutes per day.

Regular classroom instruction began following the pre-tests. Textbooks for the class included <u>Chess Rules for Students</u> by Bain (1994), <u>Chess Tactics for</u> <u>Students</u> by Bain (1993), and <u>Essential Chess Endings Explained Move by Move</u> by Silman (1992). The lessons taught on a daily basis were taken from <u>Comprehensive</u>

# Table 1

# Harkness System for Calculating Chess Ratings

Rating Difference	If Higher Rated Player Wins, Add to Winner and Deduct from Loser	If Lower Rated Player Wins, Add to Winner and Deduct from Loser	If a Draw, Add to Lower Player and Deduct from Higher Player
0 to 24	16	16	0
25 to 49	15	17	1
50 to 74	14	18	2
75 to 99	13	19	3
100 to 124	12	20	4
125 to 149	11	21	5
150 to 174	10	22	6
175 to 199	9	23	7
200 to 224	8	24	8
225 to 249	7	25	9
250 to 274	6	26	10
275 to 300	5	27	11
300 or more	4	26	12

Note. USCF-A Guide to Scholastic Chess (1997). [On-line]. Available:

http://www.uschess.org/scholastic/sc-guide.html.

<u>Chess Course (Vols. 1 & 2)</u> by Pelts and Alburt (1992). Supplementary materials were also provided from <u>Winning Chess Tactics</u> by Seirawan (1992), and <u>Chess</u> by Polgar (1994).

The instructor for the class had been an active chess player for more than 20 years and was rated as a "B" player by the USCF. In addition to holding Bachelor of Science degrees in Science Education and Petroleum Engineering and a Master of Education degree in Educational Administration and Supervision, the instructor had 14 years of classroom experience and was certified by the State of Louisiana to teach mathematics, general science, biology, chemistry, and physics.

The material in the course was divided into 24 separate lessons. Lessons varied in length from one to three class sessions depending on the complexity of the lesson. The classroom lessons were supplemented with homework assignments from a workbook, class discussions, tournaments in which students were able to apply new tactics, and games against a computer program 1 day per week.

Access to additional chess material by students was greatly enhanced by having a chess library in the classroom. This library consisted of more than 50 volumes of classic chess books, opening theory books, and biographies. Students were allowed to borrow these books for study at home.

Lesson plans and characteristics of the curriculum were of paramount importance in this study. The methods used in this case could best be described as "adhering to the philosophy of the Russian School" (Pelts & Alburt, 1992). When asked to describe the Soviet School of Chess, former World Champion Mikhail Botvinnik said, "First and foremost I must mention our scientific approach to chess. This implies a realistic attitude to the game and a critical approach towards one's own creative work" (Botvinnik, 1951, p. 2). From this comment it is obvious that the Soviets took a thorough and methodical approach to the study of chess.

Of the other studies (Horgan & Morgan, 1989; Van Zyl, 1991) that attempted to use chess instruction to improve some aspect of academic achievement, only Christiaen (1976) listed the textbook used in the class, the philosophy of instruction, or the number of instructional hours students received. Most simply stated, they compared test results of a chess-playing group to a nonchess-playing group.

According to Anderson (1982), a student must receive at least 100 hours of learning and practice to acquire any significant degree of proficiency. This study was designed to deliver approximately 100 hours of instruction before post-testing. At the time of post-testing, the treatment group had completed 86 50-minute sessions of classroom instruction and an additional 33 hours after school. The process of skill acquisition falls into three stages. First is the cognitive stage in which encoding occurs and allows the learner to crudely approximate the desired skill. Second is the associative stage in which the learner is able to eliminate initial misunderstandings and smooth-out skill performance. The third stage, the autonomous stage, is characterized by mastery of the skill (Anderson). One of the key components of chess instruction in this study was the use of visual imagery rehearsal. Research has shown that the use of mental imagery appears to facilitate meaningful learning (Alesandrini, 1982). Although Couch and Moore (1992) found that field-independent learners benefited more than field-dependent learners from the use of imagery rehearsal, this technique was still utilized in this study.

Ferrini-Mundy (1987) pre-tested 250 college calculus students for calculus achievement and spatial visualization. The students received six spatial training treatments over an 8-week period. Post-tests at the end of the semester revealed that women showed significant improvement in their calculus achievement but men did not. Ferrini-Mundy commented that the most interesting finding of the study was that practice of spatial tasks enhanced women's ability and the tendency to visualize while solving problems that involved mentally rotating two-dimensional figures in order to create three-dimensional solids. The results of these studies (Alesandrini, 1982; Couch & Moore, 1992; Ferrini-Mundy) made the use of visual imagery techniques imperative in this study. It is not known if any of the previous chess studies incorporated this methodology into their chess instruction.

Rifner (1992) described chess related outcomes expected of his subjects, such as knowledge of opening theory and being able to solve successfully particular endgame problems. However, he did not describe any specific methods or techniques used to reach those outcomes.

#### Internal Validity

In order to protect the internal validity of the study, the researcher did not participate in administering the tests to the treatment group. Neither were students informed of the results of any test measures until the completion of the study.

As stated in Chapter 1, three of the four conditions needed for knowledge transfer were provided (Palinscar & Brown, 1984; Perkins & Salomon, 1989). The fourth condition, knowing when to apply problem solving strategies to a new situation, could not be taught without using specific mathematical examples, thus biasing the study.

Another factor that increased internal validity was the fact that a poll of students who planned to enroll in the humanities class revealed that only one of the participants already knew how to play chess and that student's skill level was low. In many previous studies of the effects of chess instruction on academic performance (Horgan & Morgan, 1989; Van Zyl, 1991), researchers used subjects who already knew how to play chess, reducing the likelihood of participants actually acquiring a new skill.

### Pilot Study Results

A pilot study was conducted (Smith, 1997b) to determine if the measure of student FD/I could be changed by chess instruction. The subjects were 8 black females and 4 black males in a southern, rural, black high school. All participants were high school juniors and seniors, aged 16 and 17. Only one of the subjects, a male, knew how to play chess prior to joining the class.

The subjects were administered the Group Embedded Figures Test as a preand post-test and a t-test was used to determine if the difference in these means was significant. The pre-test mean of the females was 6.125 and for the males, 7.75 (Smith, 1997b). This indicated, incidentally, that both groups had field-dependent characteristics. The GEFT measures FD/I on a scale from 1 to 18 with scores in the 1 to 6 range indicating strong field dependence and scores in the 13 to 18 range indicating strong field independence (Witkin et al., 1971).

Following 12 weeks of chess instruction, the post-test was administered. Test reliability for the GEFT is 0.82 if the retest is not administered within 60 days. The post-test means were 9.25 for females and 8.75 for males (Smith, 1997b). Both groups were still considered field-dependent but had moved in the direction of greater field independence. The results of the t-test showed the increase was significant for females at the .05 level, but there was no significant change for the males. One proposed explanation of these results is that male players had already developed their spatial abilities to a large extent and had little room for improvement. The female subjects scored much lower on the pre-test, as well as on the spatial ability test, indicating they had greater room for improvement in that skill. Consistent with their movement toward greater field independence, the females also demonstrated more competitive behaviors at the end of the instructional period than at the beginning.

Analysis of the GEFT pre-test also revealed that the difference in test scores could be used to predict the outcome of chess matches between students. The following probability table (see Table 2) was developed after students had completed 60 games of a class round-robin tournament (Smith, 1997a). Scores on the GEFT were able to predict which of the subjects would develop greater proficiency at chess.

It is reasonable to surmise that at least one of the abilities needed for greater chess skill can be measured by the GEFT. However, due to the limitations of the pilot study it was not possible to determine which supplementary ability the GEFT was measuring.

### Pre-test Data Analysis

Pre-test data from this study were analyzed using the SPSS-X (SPSS Inc., 1988) computer program. Analysis of Variance (ANOVA) was used to determine if any significant differences existed between the treatment group and control group in their scores on the California Achievement Test-Mathematics Section, GEFT, Spatial Visualization Test, and Matrix Analogies Test (Cothron, Giese, & Rezba, 1993).

# Table 2

GEFT Test Difference	Winning Probability for Higher GEFT	
8+	99%	
5-7	89%	
2-4	75%	
0-1	50%	

# Winning Probabilities Based on GEFT Scores

Correlations between the variables were also calculated for the pre-test data. Finally, multiple regression was used to determine which attribute measured by the test instruments contributed the greatest variance to mathematics achievement by group and by gender.

### Post-test Data Analysis

A 2 X 2 Multivariate Analysis of Covariance (MANCOVA) was used to determine if significant differences existed between the groups on the post-test results. MANCOVA adjusts the dependent means for initial differences in the treatment and control groups (Dunn & Clark, 1974). Analysis of post-test scores directly addressed the four stated hypotheses of the study.

Other statistical methods utilized in analyzing post-test data included: analysis of variance, and factor analysis to determine what factors were actually determine what factors were actually influencing the outcomes of the tests. Results of the individual tests were finally converted to z-scores in order to measure more accurately the effect of the variable selected by factor analysis.

# CHAPTER 4

# **RESULTS OF DATA ANALYSIS**

This chapter describes the results of the study whose purpose was to determine the effects of chess instruction on the mathematics achievement of southern, rural, black, secondary students. The effects of chess instruction on the students' level of field dependence, spatial visualization ability, spatial orientation ability, and non-verbal reasoning were also examined. Results are presented in the following order: (1) descriptive data of participants, (2) correlation analysis of pretest data, (3) hypothesis testing, (4) correlation analysis of post-test data, and (5) summary of post hoc analysis.

# **Descriptive Data of Participants**

Subjects in this quasi-experimental study were 39 black students, ages 16 to 17 in a southern, rural, high school. The treatment group, those receiving 18 weeks of chess instruction, consisted of 11 females and 8 males. These 19 students were enrolled in a high school humanities class. The control group was comprised of 10 female and 10 male volunteers from the general high school population. Members of the control group were not enrolled in the humanities class and received no chess instruction during the study. All participants in the study were juniors or seniors who had already passed the Louisiana Graduation Exit Examination (GEE) for mathematics.

### Correlation Analysis of Pre-Test Data

Correlation analysis was used to determine the strength of linear relationships between the scores of the different pre-tests. As stated in Chapter 2, several researchers had found significant correlations between mathematics achievement and scores on the Guilford-Zimmerman Spatial Visualization Test (Burnett, Lane, & Dratt, 1979; Pearson & Ferguson, 1989); mathematics achievement and scores on the Matrix Analogies Test-Short Form (Bardos & Prewett, 1991); and mathematics achievement and scores on the Group Embedded Figures Test (Casey, Nuttall, Pezaris, & Benbow, 1995; Cooperman, 1980; Kagan & Zahn, 1975).

Five pre-tests consisting of the mathematics section of the California Achievement Test (CAT) Level 20, the Group Embedded Figures Test (GEFT), the Matrix Analogies Test-Short Form (MAT-SF), the Guilford-Zimmerman Spatial Visualization Test (SV), and the Guilford-Zimmerman Spatial Orientation Test (SO) were administered to all 39 participants during the third week of September, 1997. Significant correlations (see Table 3) were found among students' scores on all five test instruments of the pre-tests.

# Table 3

# Pre-test Correlations

Correlation Coefficients	1	2	3	4	5
1. CAT		.4288*	.6304***	.5647***	.5006***
2. GEFT			.7459***	.6432***	.4788*
3. MAT-SF			**	.7577 ***	.6545***
4. SV					.6881***
5. SO					

\*p < .05. \*\*\*p < .001.

### Hypothesis Testing

In order to test the null hypotheses a 2 X 2 multivariate analysis of covariance (MANCOVA), comparing post-test means by group (treatment and control) and gender, was used. Although analysis of variance of the pre-test scores found no significant differences between the groups, MANCOVA was nevertheless chosen to analyze the post-test scores in order to account for any interaction between the instruments and any differences between groups, no matter how small those differences might have been.

However, further examination of the MANCOVA results revealed that with one exception, the only significant covariate for each test was the score on the corresponding pre-test. This exception was the MANCOVA of the MAT-SF where the significant covariates were the pre-tests of the MAT-SF, GEFT, and SO.
Therefore, MANCOVA was used to analyze the results of the MAT-SF, and ANCOVA was used to analyze the results of the CAT, GEFT, SV, and SO.

# Effects of Chess Instruction on Mathematics Achievement

Ho1: Chess instruction will have no effect on the mathematics achievement of the treatment group.

The mean score of the treatment group was significantly higher than the mean score of the control group on the post-test of the CAT,  $\underline{F}(1,38) = 4.14$ ,  $\underline{p} < .043$  (see Table 4). Adjusted means were 62.75 for the treatment group and 60.12 for the control group (see Table 5). This result did not support hypothesis 1. The null hypothesis was, therefore, rejected.

#### Table 4

Source	<u>df</u>	Ē	
	•	A 1 4 m	
Group (G)	1	4.14*	
Gender (G)	1	5.52*	
GXG	1	.99	
Covariate			
CAT Pre-test	1	851.11***	
$\underline{S}$ = within group			
error	38	(15.15)	

# 2 X 2 ANCOVA of CAT Post-test Scores by Group and Gender

<u>Note.</u> Values enclosed in parentheses represent mean square error. Effect size for Group = .13; Sex = .11; Group X Sex = .03. \*p < .05. \*\*\* p < .001.

### Table 5

Group	Pre-test Mean	Post-test Mean	Adjusted Mean	Ē	
Treatment	55.79	61.63	62.75	4.14*	
Control	58.55	61.60	60.10		

Adjusted	Post-test	Means of	CAT	<b>Scores</b>

\***p** < .05.

The mean score for the females was also significantly higher than the mean score for the males on the CAT,  $\underline{F}(1,38) = 5.52$ ,  $\underline{p} < .025$ . This result will be discussed further in the summary of post hoc analysis.

# Effects of Chess Instruction on Field Dependence/Independence

Ho2: Chess instruction will have no effect on the degree of Field Dependence/Independence of the treatment group.

The mean score of the treatment group was significantly higher than the mean score of the control group on the post-test of the GEFT (see Tables 6 and 7). This result was consistent with the pilot study (Smith, 1997a) on the effects of chess instruction on GEFT scores described in Chapter 3. The group receiving chess instruction scored significantly higher on the GEFT post-test,  $\underline{F}(1,38) = 6.02$ , p < .019. This result did not support hypothesis 2. The null hypothesis was, therefore, rejected.

# Table 6

# 2 X 2 ANCOVA of GEFT Post-test Scores by Group and Gender

Source	df	<u>F</u>	
Group (G)	1	6.02*	
Gender (G)	1	.57	
GXG	1	.00	
Covariate GEFT Pre-test	I	39.72***	
$\underline{S}$ = within group error	38	(3.83)	

<u>Note.</u> Values enclosed in parentheses represent mean square error. Effect size for Group = .13; Sex = .02; Group X Sex = .00. Observed power for Group = .66; Sex = .05; Group X Sex = .04. \*p < .05. \*\*\* p < .001.

# Table 7

Adjusted Post-test Means of GEFT Scores

Group	Pre-test Mean	Post-test Mean	Adjusted Mean	<u>F</u>	
Treatment	7.58	9.79	9.63	6.02*	
Control	7.25	7.90	8.07		

\*p < .05.

# Effects of Chess Instruction on Spatial Ability

Ho3: Chess instruction will have no effect on the level of spatial ability of the treatment group.

The mean score of the treatment group was significantly higher than the mean score of the control group (see Tables 8 and 9) on the post-test of the SV, <u>F</u> (1, 38) = 14.13, p < .001. The curriculum used to teach chess in this study emphasized the visual skills of pattern recognition and visual imagery. This was accomplished by having students solve sets of chess problems that required them mentally to manipulate the pieces about the board.

# Table 8

Source	<u>df</u>	Ē	
Group (G)	1	14.13***	
Gender (G)	1	3.26	
G X G	1	.11	
SV Pre-test	1	154.81***	
error	38	(14.26)	

2 X 2 ANCOVA of SV Post-test Scores by Group and Gender

<u>Note.</u> Values enclosed in parentheses represent mean square error. Effect size for Group = .30; Sex = .10; Group X Sex = .00. Observed power for Group = .95; Sex = .42; Group X Sex = .05. \*\*\* p < .001.

### Table 9

Group	Mean	Mean	Mean	E	
Treatment	7.30	13.09	13.12	14.13***	
Control	7.36	8.73	8.70		

Adjusted Post-test Means of SV Scores

\*\*\*p < .001.

Alesandrini (1982) found that the use of mental imagery appeared to facilitate meaningful learning. Couch and Moore (1992) found that although most students can benefit from the use of imagery rehearsal techniques, fieldindependent students benefit more than field-dependent students.

The results of the ANCOVA of the SO post-tests (see Tables 10 and 11) found the mean scores of the control group significantly higher than the mean scores of the treatment group,  $\underline{F}(1, 38) = 4.22$ ,  $\underline{p} < .048$ . This was the only instrument of the five used in this study on which the control group scored higher than the treatment group. Considering the high correlations that exist between the instruments used in this study, this result was extremely inconsistent. One possible explanation was that several members of the treatment group complained that they had already taken tests in other classes that day and were very tired.

Source	<u>df</u>	Ē	
Group (G)	1	4.22*	
Gender (G)	1	2.12	
GXG	1	.24	
Covariate			
SO Pre-test	1	68.74***	
S = within group			
error	38	(32.76)	

### 2 X 2 ANCOVA of SO Post-test Scores by Group and Gender

<u>Note.</u> Values enclosed in parentheses represent mean square error. Effect size for Group = .11; Sex = .06; Group X Sex .01. Observed Power for Group = .51; Sex = .29; Group X Sex = .05. \*p < .05. \*\*\*p < .001.

Table 11

Adjusted Post-test Means of SO Scores

Group	Pre-test Mean	Post-test Mean	Adjusted Mean	<u>F</u>	
Treatment	9.72	10.66	10.10		
Control	5. <b>98</b>	13.08	13.92	4.23*	

\*<u>p</u> < .05

The fact that the treatment group scored significantly higher on the SV posttest, and the control group scored significantly higher on the SO post-test, did not support the null hypothesis. The null hypothesis was, therefore, rejected.

# Effects of Chess Instruction on Nonverbal Reasoning Ability

Ho4: Chess instruction will have no effect on the nonverbal reasoning ability of the treatment group.

The mean score of the treatment group was significantly higher than the mean score of the control group on the post-test of the MAT-SF (see Tables 12 and 13). This result was not unexpected due to the high correlation between the MAT-SF and the other instruments used in the study.

#### Table 12

#### 2 X 2 MANCOVA of MAT-SF Post-test Scores by Group and Gender

Source	<u>df</u>	<u>F</u>	
Group (G)	1	4.72*	
Gender (G)	1	6.62*	
GXG	1	.04	
Covariates			
GEFT Pre-test	I	3.34**	
SO Pre-test	1	2.80**	
MAT-SF Pre-test	1	4.19***	
S = within group			
error	38	(7.24)	

<u>Note.</u> Values enclosed in parentheses represent mean square error. Effect size for Group = .17; Sex = .10'; Group X Sex = .00. Observed Power for Group = .49; Sex = .35; Group X Sex = .32. \*p < .05. \*\*p < .01. \*\*\*p < .001. This result did not support the null hypothesis. The null hypothesis was, therefore, rejected.

#### Table 13

#### Adjusted Post-test Means of MAT-SF Scores

Group	Pre-test Mean	Post-test Mean	Adjusted Mean	<u>F</u>	
Treatment	18.00	21.53	21.01	4.72*	
Control	17.20	18.45	18.91		

\*p < .05.

# Summary of Post Hoc Analysis

# ANCOVA of Female Mathematics Achievement by Group

After determining that the treatment group scored significantly higher than the control group,  $\underline{F}(1,38) = 4.14$ ,  $\underline{p} < .043$  (see Table 5), and that the females scored significantly higher than the males,  $\underline{F}(1,38) = 5.52$ ,  $\underline{p} < .025$  (see Table 5), it was decided to re-examine the data in order to determine more closely what type of interaction was occurring. A one-way ANCOVA by group was conducted on the female post-test scores of mathematics achievement using the CAT pre-test scores as covariate. This result showed that treatment group females scored significantly higher than control group females (see Tables 14 and 15),  $\underline{F}(1,18) = 6.86$ ,  $\underline{p} < .017$ .

# Table 14

One Way	ANCOVA	of Econolo CAT	Saaraa hu Gaaya
One-way	ANCOVA	of remaie CAT	Scores by Group

Source	<u>df</u>	Ē	
Group (G) Covariate	1	6.86*	
CAT Pre-test $S =$ within group	1	402.31***	
error	20	(11.59)	

<u>Note</u>. Values enclosed in parentheses represent mean square error. Effect size for Group = .28.\* p < .05. \*\*p < .001.

#### Table 15

Adjusted Post-test Means of Female CAT Scores

Group	Pre-test Mean	Post-test Mean	Adjusted Mean	<u>F</u>	
Treatment	58.82	63.64	63.27	6.86*	
Control	58.00	59.00	59.37		

\* <u>p</u> < .05

A one-way ANCOVA of male mathematics achievement by group was conducted. No significant difference was found. The results of these one-way ANCOVAs indicated that chess intervention had a significant effect on the female treatment group members only and no significant effect on the male treatment group members. The statistically significant difference between male and female mean scores on the post-test of the CAT was due only to the treatment group females mean score.

### Post-test Factor Analysis

Factor analysis of the instruments used in this study and chess rating was conducted because of the high correlations between these measures. Only one variable was extracted (see Figure 1). It was imperative to identify the characteristics of this variable and make a determination of its effects on chess ability and each instrument used in the study.





Figure 1. Eigenvalue Plot of Factor Variables.

Waber (1997a) recognized the consistent correlation of field-dependence and spatial ability and proposed that they shared a fundamental underlying mechanism. For the purpose of this study, this underlying factor was labeled "spatially based cognition" (SBC). Table 16 lists the variance contributed by SBC to chess ability and the other scores measured by the instruments used in this study.

In order to determine if the level of SBC was affected by the intervention of chess instruction, the results of the pre-tests for each instrument were converted to z-scores and then added together to produce a mean score for each study subject. The same procedure was used on the post-test scores. An ANCOVA of the post-test z-score means was conducted using the pre-test z-score means as the covariate (see Table 17). The treatment group scored significantly higher than the control group,  $\underline{F}(1,38) = 7.75$ , p < .01.

# Table 16

Variance Contributed by SBC to Each Test Measure ar	d Chess Rating

Instrument	Variance	
CAT	.74	
GEFT	.84	
SV	.86	
SO	.75	
MAT	.97	
Chess Rating	.87	

# Table 17

Source	<u>df</u>	<u>F</u>	
Group (G)	1	7.75**	 
Gender (G)	1	.234	
GXS	1	.11	
Covariate			
SBC Pre-test	1	843.11***	
S = within group			
error	38	(6.67)	

2 X 2 ANCOVA of SBC Post-test z-Scores by Group and Gender

Note. Values enclosed in parentheses represent mean square error. \*\*p < .01. \*\*\*p < .001.

One-way ANCOVA of female post-test SBC scores by group indicated that treatment group females scored significantly higher than control group females (see Table 18). A similar one-way ANCOVA of male post-test SBC scores revealed no significant difference. This was further evidence that the intervention of chess instruction had a significant effect on the treatment females, but no significant effect on the treatment males.

# <u>Mathematics Achievement</u> <u>Regression Analysis by Gender</u>

Regression analysis using mathematics achievement and scores on the GEFT, SV, SO, and MAT as dependent variables was originally planned in order to

determine exactly which skills measured by these instruments contributed the greatest variance to mathematics achievement for males and females. However, due

Table 18

Source	<u>df</u>	<u>F</u>	
Group	1	8.06**	
Covariate	1		
SBC Pre-test $S = $ within group	1	223.01***	
Error	20	(.66)	

# One-Way ANCOVA of Female Post-test SBC Scores

Note. Values enclosed in parentheses represent mean square error. \*\* p < .01. \*\*\* p < .001

the result of factor analysis, which showed that SBC was the underlying variable effecting each instrument, the results of any regression analyses would have been meaningless.

# CHAPTER 5

# DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

#### Introduction

Over the past 35 years there have been several studies correlating mathematics achievement and general intelligence to the cognitive style construct of field dependence/independence (Cooperman, 1980; Kagan & Zahn, 1975; Mrolsa, Black, & Hardy, 1987; Pearson & Ferguson, 1989). Research has also found significant correlations between mathematics achievement and spatial ability (Cooperman; Tracy, 1987; Voyer, 1996).

Much of the achievement gap in mathematics between genders and races can be directly attributed to the manner in which individuals perceive their surroundings and their ability to manipulate objects mentally (Kagan & Zahn, 1975; Pearson & Ferguson, 1989; Voyer, 1996). Even more alarming is the fact that this achievement gap between white males, minorities, and females widens, particularly during the high school years (Burnett, Lane, & Dratt, 1979; Kagan & Zahn; Kush, 1996; Moore & Smith, 1987).

It was the purpose of this study to determine if learning to play chess would have a positive effect on the mathematics achievement of southern, rural, black, secondary students. Mathematics and chess both require practitioners to use visual imagery, spatial visualization, logical thinking, and problem solving skills. The model for this study was based on the assumption that knowledge and skills acquired in one domain could be transferred to other domains by the individual.

The subjects in this study had very little previous knowledge of the game of chess. Only one male student knew how to play before the study began, and his level of play was quite low. The chess instruction the students received was based on the curriculum developed by Pelts and Alburt (1992) and emphasized spatial visualization, visual imagery, logical thinking, and problem solving.

Although several studies (Christiaen, 1976; Horgan, 1987; Van Zyl. 1991) have dealt with the effects of chess on academic achievement, virtually all have used elementary and middle school students as subjects. Van Zyl claimed that middle school students who play chess have greater reasoning ability, more intense concentration, greater task perseverance, better sequencing skills, and greater attention span. If chess could improve the reasoning ability, concentration, perseverance, and sequencing skills of middle school students, then the high school setting, where the achievement gap in mathematics has been observed to widen, was an ideal choice of setting to study the effects of chess instruction.

The subjects in this study were 39 high school juniors and seniors enrolled in a southern, rural, black, secondary school. The treatment group, those that received chess instruction, was comprised of 11 female and 8 male students in a

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humanities class. The remaining students, 10 females and 10 males, were volunteers from the general student population.

All 39 students were administered the Group Embedded Figures Test (GEFT), Matrix Analogies Test-Short Form (MAT-SF), Guilford-Zimmerman Spatial Visualization Test (SV), Guilford-Zimmerman Spatial Orientation Test (SO), and the mathematics section of the California Achievement Test (CAT), Level 20, during the third week of September, 1997. Both groups were tested again with the same instruments after the treatment group had received 18 weeks of chess instruction. The criterion for determining significance was set at the .05 level.

#### **Discussion of the Findings**

The results of four of the five post-tests were analyzed simultaneously with a 2 X 2 ANCOVA and one with a 2 X 2 MANCOVA. By using this method, group post-test means were adjusted by the significant covariates derived from all five pre-tests. The five post-tests were analyzed for main effects by group (treatment and control), gender (male and female), and group by gender.

ANCOVA results for the CAT showed that the treatment group scored significantly higher than the control group in mathematics achievement,  $\underline{F}(1,38) =$ 4.49,  $\underline{p} < .042$ . This was consistent with the results of Christiaen (1976) and Van Zyl (1991) in their studies comparing the academic achievement of chess playing students versus non-chess playing students. The notable difference in this example was that subjects in this study were high school students while Christiaen and Van Zyl studied middle school students. Christiaen also measured achievement by comparing grades students received in their classes rather than using a standardized instrument (Christiaen). This result rejected hypothesis 1, which stated that chess instruction would have no effect on the mathematics achievement of the treatment group.

The ANCOVA of the GEFT post-test scores also showed that the treatment group scored significantly higher than the control group ( $\underline{F} = 4.54$ ,  $\underline{p} < .041$ ). Although field dependence/independence has been shown to be stable over time (Witkin, Goodenough, & Karp, 1967), it should be pointed out that the researchers in that study were measuring and recording levels of FD/I and not attempting to bring about change. The effects of interventions to alter an individual's level of FD/I could not be found in the literature. This result did not support hypothesis 2, which stated that chess instruction would have no effect on the field-dependence/ independence of the treatment group.

One of the inconsistent findings of this study was the similarity of GEFT scores between males and females. Several studies (Goodenough & Karp, 1961; Perney, 1976; Witkin & Goodenough, 1977) have repeatedly demonstrated the tendency of males to score significantly higher than females on tests of fielddependence/independence. However, in this study there was no significant difference between genders. This anomaly may have simply been a characteristic of the subjects used in the study.

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The ANCOVA results of the SV ( $\underline{F} = 14.13$ ,  $\underline{p} < .001$ ) and the MAT-SF ( $\underline{F} = 6.09$ ,  $\underline{p} < .019$ ) also concluded that the mean scores of the treatment group were significantly higher than the mean scores of the control group on both of those measures. Several studies have shown that strong correlations exist between scores on the SV and mathematics achievement (Burnett, Lane, & Dratt, 1979), scores on the GEFT and mathematics achievement (Mrolsa, Black, & Hardy, 1987), and scores on the MAT-SF and mathematics achievement (Bardos & Prewett, 1991; Prewett & Farhney, 1994). These results rejected hypothesis 3, which stated that chess instruction would have no effect on the spatial ability of the treatment group, and hypothesis 4, which stated that chess instruction would have no effect on the nonverbal reasoning of the treatment group.

The control group scored significantly higher than the treatment group on only one measure, the SO, <u>F</u> (1,38) = 4.23, p < .048. As previously stated, this difference may have been due to the fact that the treatment group subjects were tired.

Scores on the GEFT, MAT-SF, SV, SO, chess ability ratings, and tests of mathematics achievement are extremely dependent upon the perceptual skills of the test taker. The high correlation between these measures suggests they share a common factor. This common factor may be closely related to the skill needed to perform mental rotation activities. It is also reasonable to suggest that any activity

that brings about an improvement on one instrument will have a corresponding positive effect on the others.

This supposition was confirmed by factor analysis. The factor that underlies all the aforementioned skills was labeled spatially based cognition (SBC) in this study. It accounted for a very large amount of the variance in each of the skills measured by the test instruments in this study.

One of the more interesting findings in the study was the significant correlation ( $\mathbf{r} = .5445$ ;  $\mathbf{p} < .013$ ) between chess rating and mathematics achievement. Several authors have argued for (Norwood, 1993) and against (DeGroot, 1978; Holding, 1985) the existence of a relationship between chess skill and mathematical ability. Chess ability also significantly correlated with the MAT-SF ( $\mathbf{r} = .8723$ ;  $\mathbf{p} < .001$ ) and the SV ( $\mathbf{r} = .6406$ ;  $\mathbf{p} < .002$ ). Norwood seemed to agree with Van Zyl's (1991) conclusions, crediting chess with the ability to create enthusiasm that spills over into other activities, increases problem solving ability, and increases one's ability to focus on the problem at hand.

The correlation between mathematics and chess ability may be more related to their link with SBC than to any specific cognitive connection between the two. In comparing the pre- and post-scores of the factor SBC, the treatment group scored significantly higher than the control group,  $\underline{F}(1,38) = 7.75$ ,  $\underline{p} < .009$ . Acceptance of the idea that a fundamental skill linking several spatial, cognitive, and academic activities could have serious implications for educational planners.

It is also very important to point out that the ANCOVA of female CAT scores by group found that treatment group females scored significantly higher than the control group females. The ANCOVA of male CAT scores by group revealed no significant difference between the treatment and control groups ( $\mathbf{F} = 8.06$ ,  $\mathbf{p} < .001$ ). This clearly showed that the female members of the treatment group benefited much more from the spatial-treatment provided in the form of chess instruction, than did males.

This result is supported by a study of 250 entering college calculus students (Ferrini-Mundy,1987) that found the scores of female students improved significantly after receiving six spatial-training sessions over an 8-week period. This study was an attempt to use chess as a vehicle to stimulate the development of spatial skills and logical thinking. Unless methods can be found to enable students with low spatial abilities to become more proficient in mathematics and other academic disciplines that require the use of spatial visualization and creative problem-solving techniques, many career and educational opportunities may remain closed to them

The same result was obtained when an ANCOVA was conducted on each gender using the SBC z-score means. This once again indicated that female treatment group members benefited more than male treatment group members when receiving spatial-training and that those benefits could be verified on several instruments.

#### **Conclusions**

The participants in this study who received chess instruction scored significantly higher on their post-test of mathematics achievement than the control group members who did not receive chess instruction. The corresponding significant results on other tests of perceptual, spatial, and nonverbal reasoning skills suggest that the intervention of chess instruction had a significant impact on these individuals. The discovery of an underlying factor, which significantly contributes to the variance of scores on these tests, is of major importance. This study suggested that chess instruction improved this underlying factor and in turn improved scores on several of the test instruments. It may be possible to improve achievement in other academic disciplines that make use of spatial, perceptual, and problem solving abilities.

Another factor that added credibility to this study was the fact that only one of the treatment subjects knew how to play chess before the study began. This study presented a clear picture of what chess intervention can do, as opposed to studies of post hoc analysis comparing a group of chess playing students against a group of non-chess playing students.

It is also important to recognize the fact that, as a whole, participants in both the treatment group control groups were field-dependent. Pre-test means were 7.58 for the treatment group and 7.25 for the control group. Scores below 10 are typically categorized as field-dependent.

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The treatment group in general, and the treatment group females in particular, showed significant improvement in mathematics achievement. However, it is not reasonable to make the claim that chess instruction could be responsible for improvements in such fundamental mathematics skills as multiplication, the ability to correctly work algebra problems, or to perform geometric proofs. It is well within reason to suggest, as did Van Zyl (1991), that chess instruction brought about changes in the subjects that produced more patience, perserverance, concentration, and creativity. These qualities could then be applied to other academic areas, such as mathematics.

According to Van Zyl (1991), a chess player's ability to reason is further developed when he assesses moves and variations. This involves intense concentration, anticipation, classification, transcending, the adoption of priorities, and increased logical thinking ability.

In addressing a chess player's ability to classify, evaluate, and select a plan of action, DeGroot (1978) stated:

An experienced chess player will follow a hierarchical pattern in an attempt to strengthen his position. He conducts a systematic investigation and makes a choice out of the moves that he has investigated. The course of the planning and the weighing of priorities does not necessarily follow a fixed pattern. (p. 264-265) In addressing the aspects of creativity involved in playing chess DeGroot (1978) observed:

A chess player is continuously creating new positions. After every move he thinks up new variations either to strengthen his own position, entice his opponent into a trap, or to put the latter into such a position that he will be forced to make mistakes. When it appears that his own position is being weakened, he will stop trying to prove that a particular move is a good one, and start from scratch, purposefully reconstructing a whole new concept. (p. 218)

A chess player's perseverance often determines victory or defeat at the board. When asked in a written survey, what they enjoyed most about playing chess, 15 of the 19 students responded, "Winning." Increased patience, perseverance, concentration, and creativity among the students, who received chess instruction, cannot be ruled out as a contributing factor in their improved mathematics achievement scores.

However, it would be inadvisable to infer that chess may be the panacea to cure low scores in mathematics achievement by minority and female students. This study was conducted with a small number of participants, all of whom were southern, rural, black students and the results obtained with this group may not be generalizable to other populations.

#### Recommendations

1. Further study is needed to replicate these findings. This should be done with subjects from a variety of racial, cultural, and socio-economic backgrounds in order to determine which populations can benefit from chess instruction.

2. Further study is necessary to develop further the curriculum used in this study. In addition to improving the material itself, different methodologies and teaching techniques may also need to be developed to address the needs of specific student populations.

3. More research is needed to understand the underlying factor labeled spatially based cognition in this study. Understanding this factor could have farreaching implications for the future of curriculum development and the development of methods to improve students' levels of spatial ability, thereby improving their ability in academic disciplines that are heavily dependent on spatial ability. APPENDIXES

Appendix A

Human Subjects Committees

Approval Letters



OFFICE OF VICE PRESIDENT FOR RESEARCH AND DEVELOPMENT

#### MEMORANDUM

- TO: James P. Smith. Dr. Carolvn Talton and Dr. Horace Maxile
- FROM: Margaret Nolar
- SUBJECT: HUMAN USE COMMITTEE REVIEW
- DATE: July 21, 1997

In order to facilitate your project. an **EXPEDITED REVIEW** has been done for your proposed study entitled:

#### The <u>Effects of Chess Instruction on the Mathematics Achievement of</u> <u>Southern. Rural. Black Secondary Students</u> (# 1-KJ\_)

The proposed study procedures were found to provide reasonable and adequate safeguards against possible risks involving human subjects. The information to be collected may be personal in nature or implication. Therefore, diligent care needs to be taken to protect the privacy of the participants and to assure that the data are kept confidential. Further, the subjects must be informed that their participation is voluntary.

Since your reviewed project appears to do no damage to the participants, the Human Use Committee grants approval of the involvement of human subjects as outlined.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the University for three years after the conclusion of the study.

If you have any questions, please give me a call at 257-5075.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM

POST OFFICE BOX 7923 • RUSTON LA 712T2-0029 • TELEPHONE (313) 257-2924 • FAX (318) 257-4487 • emoli research@toTech.edu An Iogal officerteur Diummaster

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Grambling State	University -Coll	lege of Education
Human Subje	cts Exemption*	Review Form

[Researcher Name's] James Paul Smith
I Research Proposal Title A Quantitative Analysis of the
III. Exemption must meet the all following conditions: (1) no treatment is associated with participants in the investigation, (2) appropriate established procedures to assure anonymity, (3) confidentiality clearly explained in the informed consent form for subjects, and (4) subjects exposed to no more than minimum risk.
The Human Subjects Committee determines whether or not a proposed research is exempt. Research proposals considered for this category include (check all that apply for your research):
research involving surveys, interviews, or observation of each participant's behavior.
Zresearch conducted in established educational settings involving normal educational practice
such as comparison among curricula, instructional strategies, or classroom management
methods.
research involving use of educational tests.
research involving the collection or study of existing data, documents, and records.
Human Subjects Committee Action: Approved Disapproved
Signature of Human Subjects Committee Chair
- Athrea de

Appendix B

Parent and Subject Consent Forms

#### PARENTAL CONSENT FORM

The following is a brief summary of the project in which your child is asked to participate.

TITLE: A Quantitative Analysis of the Effects of Chess Instruction on the Mathematics Achievement of Southern, Rural, Black Secondary Students.

**PURPOSE OF STUDY:** To determine if the skills acquired in learning to play chess will improve mathematics achievement.

**PROCEDURE:** The subject group and a control group will be administered a battery of tests in late August, 1997. The subject group will then receive 18 to 24 weeks of chess instruction. Chess instruction will be given five days per week during the first six-weeks grading period and three days per week after that time with two hours of instruction after school to be attended on a volunteer basis. Following this period the test battery will be repeated.

**INSTRUMENTS:** The Group Embedded Figures Test by Herman Witkin: the Mathematics Section of the California Achievement Test (Level 20): the Guilford-Zimmerman Tests of Spatial Orientation and Spatial Visualization: and the Matrix Analogies Test-Short Form by Jack Naglieri.

#### RISKS: None

#### **BENEFITS/COMPENSATION:** None

Dr. Mary Livingston

I.\_\_\_\_\_\_\_, attest with my signature that I have read and understood the description of the study. "A Quantitative Analysis of the Effects of Chess Instruction on the Mathematics Achievement of Southern. Rural, Black Secondary Students." and its purposes and methods. I understand that my child's participation in this research is strictly voluntary and his/her participation or refusal to participate in this study will not affect his/her relationship with Grambling High School or his/her grades in any way. Further, I understand that he/she may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of his/her survey will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative.

(Student's Name)	(]	Parent or Guardian)	(date)
CONTACT INFORMATION:	The researchers lis	ted below may be reached to a	nswer questions:
Dr. Horace Maxile	274-6153	Dr. Carolyn Talton	257-2794
Mr. James P. Smith	274-6153	-	
The Human Subjects Com	mittee of Louisiana	I Tech University may also be	contacted if a problem
cannot be discussed with the resea	rchers:		
Dr. Terry McConathy	257-2924	Ms. Margaret Nolan	257-5075

257-4315

#### STUDENT CONSENT FORM

The following is a brief summary of the project in which you are asked to participate.

TITLE: A Quantitative Analysis of the Effects of Chess Instruction on the Mathematics Achievement of Southern, Rural, Black Secondary Students.

**PURPOSE OF STUDY:** To determine if the skills acquired in learning to play Chess will improve mathematics achievement.

**PROCEDURE:** The subject group and a control group will be administered a battery of tests in late August, 1997. The subject group will then receive 18 to 24 weeks of chess instruction. Chess instruction will be given five days per week during the first six-weeks grading period and three days per week after that time with two additional hours of instruction after school to be attended on a volunteer basis. Following this period, the test battery will be repeated.

INSTRUMENTS: The Group Embedded Figures Test, a standard test distributed by Consulting Psychologists Press. Inc.: the Mathematics Section of the California Achievement Test (Level 20): the Guilford-Zimmerman Tests of Spatial Orientation and Spatial Visualization: and the Matrix Analogies Test-Short Form by Jack Naglieri.

RISK: None

#### BENEFITS/COMPENSATION: None

(Student's Signature)		(Date)	
CONTACT INFORMATION:	The researchers	listed below may be reached to	answer questions:
Dr. Horace Maxile	274-6153	Dr. Carolyn Talton	257-2794
Mr. James P. Smith	74-6153		

The Human Subjects Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the researchers:

Dr. Terry McConathy	257-2924	Ms. Margaret Nolan	257-5075
Dr. Mary Livingston	257-4315		

Appendix C

Description of the California Achievement Test

Mathematics Section (Level 20)

# Description of the Mathematics Section of the

#### California Achievement Test (Level 20)

The California Achievment Test (Level 20) is designed as an achievement tool for 10th grade high school students. It is designed to be administered in the early fall semester and repeated in the spring semester. The mathematics section of the test is divided into two parts. The first part is comprised of 50 problems that deal strictly with computational skills. Part two, dealing with mathematics concepts and application of those concepts, is composed of 55 problems. The student's total score is determined by adding the scores of both test together. It has a test, re-test reliability coefficient of .88 (CTB-MacMillan/McGraw-Hill, 1992).

Appendix D

Description of the Guilford-Zimmerman

Spatial Orientation Test

### Description of the Guilford-Zimmerman

#### Spatial Orientation Test

The Guilford-Zimmerman Spatial Orientation Test is one of six parts of the Guilford-Zimmerman Aptitude Survey. Its authors consider it to be useful in predicting the success of machine operators, for spatial orientation has been found to contribute to the variances of scores in a number of psychomotor tests in which mechanical devices are manipulated (Guilford & Zimmerman, 1981). This test measures an individual's ability to perceive relations between visual objects. It involves a separate ability for seeing visual relations between pairs of objects. The subject has 10 minutes to answer 61 items in which he/she is asked to determine the change in orientation of an observer who sees the same picture from a different perspective. It has high reliability coefficients, .89 for men and .88 for women (Guilford-Zimmerman, 1981).

Appendix E

Description of the Guilford-Zimmerman

Spatial Visualization Test
# Description of the Guilford-Zimmerman

## Spatial Visualization Test

The Guilford-Zimmerman Spatial Visualization Test is one of six parts of the Guilford-Zimmerman Aptitude Survey. Its authors believe it to be useful in predicting the success of design engineers, blueprint drawing, and learning to fly an airplane. This test directly measures an individual's ability to mentally rotate an object. This 10-minute test consists of 40 items in which the subject is told how a reference object is to be rotated and is then asked to predict the final position of another object when it is rotated in an identical fashion. It has extremely high reliability coefficients, r = .93 for females and r = .94 for males (Guilford & Zimmerman, 1981).

Appendix F

Description of the Group Embedded Figures Test

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### Description of the Group Embedded Figures Test

The GEFT was designed as an adaptation of the original individually administered Embedded Figures Test. It is designed to measure an individual's level of field dependence/independence. The test is composed of 25 items which require the individual to disembed a geometric figure from a more complex figure. The GEFT is divided into three sub-tests. The first section contains 7 simple items colored blue and white. Two minutes are allowed for this section and it is not scored. Rather, it is examined by the test grader to ascertain if the test taker understood the directions. The subject is allowed five minutes to complete each of the last two sections. Each of the remaining sections contains 9 complex geometric items colored black, white, and blue. The GEFT has been shown to have high reliability to the original EFT, r = 0.82 for males and r = 0.63 for females (Witkin, Oltman, Raskin, & Karp, 1971).

Appendix G

Description of the Matrix Analogies Test-Short Form

### Description of the Matrix-Analogies Test-Short Form

The Matrix Analogies Test-Short Form is a 25-minute group administered screening test of nonverbal cognitive ability. The version used in this study was level G, designed for students in grades 10 through 12. The test is comprised of 38 items of a progressive matrix type and is a short version of the Matrix Analogies Test-Expanded Form (Naglieri, 1985). The MAT-SF items are printed two per page in black, blue, white, and yellow colors. Students bubble in their responses on an answer sheet. The MAT-SF has a high test-retest reliability, r = 0.78 (Naglieri, 1996). Naglieri (1985) suggested that the test can be used: to help identify children who may experience discrepant performances between their nonverbal reasoning and achievement; for the assessment of nonverbal ability of in exceptional populations, such as children with communication disorders; and to assist in the assessment of children with motor problems.

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#### Curriculum Vita

James Paul Smith was born on May 18, 1951 in Shreveport, Louisiana. He lived in the Shreveport area until his graduation from Woodlawn High School in May of 1969. Upon graduation from high school he enrolled in college and graduated from Northeast Louisiana University in Monroe, Louisiana in December, 1973 with a Bachelor of Science degree in Science Education. He did not pursue a career in education, but entered the petroleum industry, eventually earning a Bachelor of Science degree in Petroleum Engineering from Louisiana Tech University in Ruston, Louisiana in November, 1982. After working in petroleum exploration in Alabama, Arkansas, California, and Texas, Mr. Smith returned to Louisiana in 1986 and began a career in education as a supervising teacher in the Grambling State University Laboratory High School in Grambling, Louisiana. In this capacity he has taught middle school Life Science and Earth Science; high school Algebra I, Calculus, Physics, Biology, Chemistry, and Humanities; and coached football and track. His girls track team won the Louisiana High School Athletic Association Class A outdoor track and field championship in 1992. Having completed the requirements for a Master of Education degree in Education Administration and Supervision in May, 1989, he was also certified as a principal and supervisor of instruction. Mr. Smith has also participated in several programs and institutes to improve science instruction and is a member of several

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professional organizations including: Phi Delta Kappa, Louisiana Science Teachers Association, Mid-South Educational Research Association, and Louisiana Educational Research Association. Mr. Smith is an avid chess player and has presented papers on the student benefits of chess instruction at the Mid-South Educational Research Association and Louisiana Educational Research Association annual meetings. He resides in Simsboro, Louisiana and may be reached at the following e-mail address: waterdog@bayou.com







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