

THE EFFECTS OF A CHESS PROGRAM
ON ABSTRACT REASONING AND PROBLEM-SOLVING
IN ELEMENTARY SCHOOL CHILDREN

BY

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ABSTRACT

Does chess make students smarter? More specifically, does a comprehensive chess education program improve a student's abstract reasoning and problem-solving skills? This study, conducted by James Celone at the Foote School in New Haven, Connecticut, sought to answer these questions by examining the performance of 19 elementary school students, ranging in age from 7 to 14, who were self-selected for a week-long program consisting of 20 hours of chess instruction. Students were tested before and after the program, using equivalent forms of the TONI-3 Test of Non-Verbal Intelligence, a valid and reliable instrument highly associated with abstract reasoning and problem solving, and using the Knight's Tour, a domain-specific instrument measuring overall chess problem-solving ability. The study found a significant increase between pre-test and post-test scores in both intelligence and domain-specific problem-solving ability. This extends and confirms earlier work done in 1975 by Christiaen in Belgium.

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CHAPTER 1. INTRODUCTION

Purpose

Chess is an exercise of infinite possibilities for the mind, one which develops cognitive abilities used throughout life: concentration, critical thinking, abstract reasoning, problem solving, pattern recognition, strategic planning, creativity, analysis, synthesis and evaluation (Ferguson, 1983). The present study investigates the differences in abstract reasoning and problem-solving ability in elementary school-aged subjects before and after a weeklong program of chess instruction. The Test of Non-Verbal Intelligence (TONI-3) and the Knight's Tour will measure the factors of interest. The TONI-3 is considered a valid and reliable instrument that has been highly associated with abstract reasoning and problem-solving (Brown, Sherbenou, and Johnsen, 1997), and has the added advantage of an average administration time of fifteen minutes. The Knight's Tour is arguably one of the most difficult and well-known chess exercises in problem-solving (Bagnall, 1998), and can be administered online (<http://enchantedmind.com/knight.htm>). Knight's Tour scores are correlated with TONI-3 scores to determine the extent to which the Knight's Tour is a valid instrument for measuring abstract reasoning.

Charles Spearman's theory of intelligence maintains, "all intellectual activities share a single common factor, called the *general factor*, or *g*" (Anastasi & Urbina, 1997, p. 310). "There are those who posit that the ability to solve problems is, in fact, the *g-factor* that Spearman

hypothesized” (Brown et al., 1997, p. 19). The present study seeks to substantiate and extend the growing body of evidence that suggests chess can be instrumental in developing higher levels of intelligence in students, which in turn could lead to increased academic success. In short, the present study attempts to answer the question, “Does chess make students smarter?”, and it considers whether a chess curriculum taught in our nation’s schools might be a beneficial addition to a student’s formal education.

Survey of Literature

Chess has been played and enjoyed by people around the world for two thousand years. If there were an award for game of the millennium, it would belong to chess. The game is said to have been invented in India around the fourth century B.C., by a Brahman named Sissa at the court of the Indian Rajah Balhait, where it was called *chaturanga*, although its earliest mention in literature occurred in a Persian romance, the Karnamak, written about 600 A.D. Alexander the Great’s conquest of India brought the game west to Persia (Lasker, 1949, pp. 3-5). It moved east from India along overland trade routes into the Orient and west from Persia into Arabia, where *chatrang*, as the game was later called, then spread across northern Africa and into Europe when the Moors invaded Spain. *Ajedrez* (as it was known by the Spanish) spread quickly through Europe and had spread even earlier north from Persia into Russia, so that before the discovery of the Americas chess had a firm and established following on three continents as a supreme fascination and test of mental ability, an aesthetic beauty enjoyed by both nobleman and peasant (or shall we say king and pawn?).

Many notable men in history made chess their favorite pastime. Fascination with the game was not lost on men like Churchill, Napoleon, Voltaire, and the great mathematician, Euler. Benjamin Franklin, in his work, The Morals of Chess, regarded chess as more than just an idle amusement, ascribing several “valuable qualities of the mind, useful in the course of human life, [that] are to

be acquired or strengthened by it, so as to become habits, ready for all occasions. For Life is a kind of Chess...” (Franklin, 1876). Franklin enumerated these qualities as “1. Foresight... 2. Circumspection... 3. Caution... and 4. Perseverance in hope of favorable resources.” In this sense, we may credit Franklin with being one of the first to hypothesize that chess strengthens “valuable qualities of the mind” and to open the inquiry concerning whether or not chess makes one smarter.

Many parallels have been drawn between mathematics, music, and chess. Lasker (1949) states:

Mathematical thinking is generally held to be more or less closely related to the type of thinking done in chess. Mathematicians are indeed drawn to chess more than most other games. What is less widely known is that very frequently mathematicians are equally strongly attracted to music. Many musicians do not reciprocate this attraction, but I firmly believe that this is mainly due to their lack of acquaintance with mathematics, and to the widespread confusion of mathematics with “figuring.”

An intriguing phenomenon that links mathematics, music and chess is the fact that child prodigies have been known only in these three fields. That children have never produced a masterwork in painting, sculpture, or literature seems only natural when we consider their limited experience of life. In music, chess, or mathematics, that experience is not needed. Here, children can shine, because native gifts are the dominant factor. Aesthetic sensitiveness and ability to think logically are certain inborn qualities. How, otherwise, could Mozart have composed a minuet, and actually written it down, before he was four years of age? How could Gauss, before he was three years old, and before he knew how to write, have corrected the total of a lengthy addition he saw his father do? How could Sammy Reshevsky play ten games of chess simultaneously when he was only six?

The reasoning ingredient in a chess combination is always of prime importance, even though a vivid imagination will make a chess player think of possibilities that will not occur to a less imaginative logician. (p. 142)

The above passage indicates abstract reasoning, a generally accepted quality inherent in both mathematics and music, is of prime importance in chess.

In the twentieth century, many educators, parents and chess experts maintain that chess education improves a host of mental abilities, including abstract reasoning and problem-solving (Schmidt, 1982; Rifner, 1997). Artise (1993) argues that “the game of chess makes one of the most important contributions to the field of education. Inherent in it is [sic] the basic principles of psychological learning theory: memory, pattern recognition, decision-making, and reinforcement.” Proponents believe that “chess belongs in schools.... Interest in chess can be generated in all groups of students regardless of cultural or economic background. Aptitude for the game is not restricted to the more scholarly students” (Hall, 1983). Peter Shaw, a computer science and chess teacher in Pulaski, Virginia, states, “The game demands both inductive and deductive reasoning. You see the kid looking at a problem, breaking it down, then putting the whole thing back together. The process involves recall, analysis, judgement, and abstract reasoning” (Graham, 1985). As Vail (1995) points out, “Chess, it seems, possesses a rare quality: Children enjoy it despite the fact it’s good for them.” Chess, with its aesthetic appeal and inherent fascination for students of all ages, is catching the attention of educators, who are beginning to realize its academic and social benefits:

To the players, the game is like an unfolding drama.... The players live through the emotions of an exciting story.... Chess has a powerful aesthetic appeal. The best chess games are works of art. They are the products of original and creative thinking.... The beauty of chess is as compelling and pleasure giving as any other art form. The endless opportunities for creating new combinations in chess are perhaps comparable to painting or music.

Several benefits accrue from the teaching and promoting of chess in schools: 1. Chess limits the element of luck; it teaches the importance of planning. 2. Chess requires that reason be coordinated with instinct [intuition]; it is an effective decision teaching activity. 3. Chess is an endless source of satisfaction; the better one plays, the more rewarding it becomes. 4. Chess is a highly organized recreation.... 5. Chess is an international language.... It can be a lifelong source of interest, amusement, and satisfaction. Chess provides more long-term benefits than most school sports (Hall, pp. 4-5).

Hall goes on to state that proficiency in chess seems to be related to “inherent logic” and “problem-solving ability.... The deeper one’s understanding of chess, the more it becomes an exercise in sheer intellect” with each game “an original creation” (pp. 6-7). Horgan (1986) agrees, stating, “teaching children to perform a complex task like chess may give them problem-solving advantages later [in life]” (p. 10). Schmidt (1982) cites three long-term goals students achieve through chess:

1. Develop analytical, synthetic and decision-making skills, which they can transfer to real life,
2. Learn to engage in deep and thorough chess research which will help them build their confidence in their ability to do academic research,
3. Gain insights into the nature of competition which will help them in any competitive endeavor (p. 7).

Chess clearly is a problem-solving tool, an “ideal way to study decision-making and problem-solving because it is a closed system with clearly defined rules” (Horgan, 1988). When faced with a problem, the first step is to “analyze [it] in a preliminary and impressionistic way: sizing up the problem” (Horgan, 1988, p. 3), possibly looking for patterns or similarity to previous experiences. “Similarity judgements may involve high levels of abstract reasoning” (Horgan, 1988, p. 3). As in mathematics, which might be defined as the study of patterns, pattern recognition in chess is of prime importance in problem solving. After recognizing similarity and pattern, a global strategy can be developed to solve the problem. This involves generating alternatives, a creative process. A good chess player, like a good problem solver, has “acquired a vast number of interrelated schemata” (Horgan, 1988, p. 3), allowing for good alternatives to quickly and easily come to mind. These alternatives must then be evaluated, using a process of calculation known as decision tree analysis, where the chess player/problem solver is calculating the desirability of future events based on the alternative being analyzed. Horgan (1988) found that “the calculation may go several to eight or ten moves ahead. This stage requires serious concentration and memory abilities...[or]...visual imagery” (p.4). Child chess experts were studied by Schneider, Gruber, Gold, and Opwis (1993), and were found able to store larger “chunks” of information, or “pre-stored schema,” than were non-expert adults, and were able to recall them much faster than the adults when reconstructing a position. Once a suitable alternative for solving the problem is reached and implemented, it can be evaluated. Chess players, like all good problem solvers, will go back and evaluate the outcome of a solution to increase their level of expertise. “Experts and potential experts want to know, even when they are successful, if there was a better alternative available to them” (Horgan 1988, p.6). According to Bloom (1956), this evaluation process is one of the most important goals of learning and should therefore be considered one of the highest educational objectives of our schools. “The tendency of chess to develop skills which may be used to deal with the complexities of life make it a valuable tool for learning. Chess needs to be an elective in the public school curriculum” (Schmidt, p. 6).

Teaching chess to children involves more than just playing the game. Chess training has the advantage of being an art, a science, and a sport (Wojcio, 1990). The search for patterns and similarity and the generation of alternatives is accelerated and refined in the teaching process. Players are trained to play both faster and slower. Horgan (1988) found the “longer analysis time [of slower play] was correlated with a deeper level of analysis...[while faster play]...develops intuitions and a global perspective” (p.7). Chess as a deductive system has been used effectively in the classroom for introducing the study of formal Euclidean geometry (Whitman, 1975). Pattern recognition, calculation, abstract reasoning, concentration, intuition, deduction, visual imagery, analysis and evaluation are factors widely recognized as attributes of intelligence. Chess has the added benefits of teaching “impatient kids the value of hard work and delayed gratification” (Drummond, 2000) and possibly of channeling anger in a socially acceptable, safe and controlled environment (Vail, 1995). Educators at Roberto Clemente School in New York report that after instituting a chess program, “incidents of suspension and outside altercations have decreased by at least 60%” (Palm, 1990). It is for these reasons that educators are adding chess to their collection of effective strategies for reaching resistant or disconnected youth (Kennedy, 1998). Does chess, then, when taught as a body of knowledge, increase or enhance intelligence? As Horgan, Horgan, and Morgan (1986) state, “chess skill is not an isolated curiosity, but rather a paradigm of highly sophisticated cognitive ability” (p. 4).

Smith and Sullivan (1997) studied the effects of chess instruction on student's level of field dependence/independence. They define field dependence/independence as "a psychological construct referring to a global versus analytical way of perceiving that entails the ability to perceive items without being influenced by the background" and note that visual perception and problem-solving/critical thinking are factors relating to both the field dependence/independence construct and chess playing ability. The study was conducted with a high school Humanities class composed of 11 African-American students who received approximately 50 hours of chess instruction and playing experience. It was found that chess instruction significantly improved field independence in the seven female subjects. There was no significant effect for the four males. According to Smith and Sullivan, "Field Independent individuals...are abstract-analytical in orientation...[and]...are known for solving problems rapidly" (p. 5). The professions of mathematics, medicine, engineering and the physical sciences tend to attract individuals with field independent characteristics, so Smith and Sullivan infer that chess instruction may be beneficial, especially to females interested in pursuing careers in these fields. "Whether or not this [significant effect on increased field independence] translates into greater mathematics achievement as reported by Christiaen... [was] beyond the scope of this study" (p. 8). The study may be criticized for non-randomness and small sample size.

Chess is found as required curricula in nearly 30 countries (Ferguson, 1995). In Russia, it has been part of the curriculum for over 40 years, where "adolescents were encouraged to play chess at a very early age to increase their problem-solving and reasoning skills" (Milat, 1997). In Vancouver, B.C., the Math and Chess Learning Center, recognizing the correlation between chess playing and math skills development, has written a series of workbooks to assist Canadian students in math (<http://www3.bc.sympatico.ca/mathchess/>). Liptrap (1997) states,

The mathematics curriculum in New Brunswick, Canada, is a text series called "Challenging Mathematics" which uses chess to teach logic from grades 2 to 7. Using this curriculum, the average problem-solving score of pupils in the province increased from 62% to 81%.

Reports from students, teachers and parents not only extol the academic benefits of chess on math problem solving skills and reading comprehension, but increased self-confidence, patience, memory, logic, critical thinking, observation, analysis, creativity, concentration, persistence, self-control, sportsmanship, respect for others, self-esteem, coping with frustration, and many other positive influences which are difficult to measure but which can make a great difference in student attitude, motivation and achievement.

The Province of Quebec, where the program was first introduced, has the best math scores in Canada. Canada consistently scores higher than the United States on international mathematics exams. Former U.S. Secretary of Education Terrell Bell encourages knowledge of chess as a way to develop a preschooler's intellect and academic readiness (Bell, 1982, pp. 178-179). The State of New Jersey passed Bill #S452 legitimizing chess as a unit of instruction. An excerpt from the bill reads as follows:

The Legislature finds and declares that:

- a) Chess increases strategic thinking skills, stimulates intellectual creativity, and improves problem-solving ability while raising self-esteem;
- b) When youngsters play chess they must call upon higher-order thinking skills, analyze actions and consequences, and visualize future possibilities;
- c) In countries where chess is offered widely in schools, students exhibit excellence in the ability to recognize complex patterns and consequently excel in math and science (Milat, 1997).

Funding for chess activity is available under the "educate America Act" (Goals 2000), Public Law 103-227, Section 308.b.2.E: "Supporting innovative and proven methods of enhancing a teacher's ability to identify student learning needs and motivating students to develop higher order thinking skills, discipline, and creative resolution methods." The original wording of this section included the phrase "such as chess" and passed both houses of Congress that way. But the phrase was later deleted in Conference Committee. (Liptrap, 1997).

In a 1987 study, Horgan found that children learn chess differently than adults: “While adults seem to progress toward expertise from a focus on details to a more global focus, children seem to begin with a more global, intuitive emphasis.” She suggests this might be a more efficient way of learning, with rapid judgements forcing “the integration of a child’s rapidly expanding knowledge base” (Horgan, 1987, p. 9).

In a Texas study of 571 regular (non-honors) elementary school students, Liptrap (1997) found the 67 who participated in a school chess club showed twice the improvement of 504 non-chessplayers in Reading and Mathematics standard scores between third and fifth grades on the Texas Assessment of Academic Skills.

In a 1992 New Brunswick, Canada, study, using 437 fifth graders split into three groups, experimenting with the addition of chess to the math curriculum, Gaudreau found increased gains in math problem-solving and comprehension proportionate to the amount of chess in the curriculum (Ferguson, 1995, p. 11).

In a Zaire study conducted by Dr. Albert Frank, employing 92 students age 16-18, the chess-playing experimental group showed a significant advancement in spatial, numerical and administrative-directional abilities, along with verbal aptitudes, compared to the control group. The improvements held true regardless of the final chess skill level attained (Ferguson, 1995, p. 2).

A four-year study in the United States, though not deemed statistically stable due to some switching of students between the control groups and experimental group, has the chess-playing experimental group consistently outperforming the control groups engaged in other thinking development programs, using measurements from the Watson-Glaser Critical Thinking Appraisal and the Torrance Tests of Creative Thinking (Ferguson, 1983).

The Venezuela "Learning to Think Project," which trained 100,000 teachers to teach thinking skills, and which involved a sample of 4,266 second grade students, reached a general conclusion that chess, methodologically taught, is an incentive system sufficient to accelerate the increase of IQ in elementary age children of both sexes at all socio-economic levels (Ferguson, 1995, p.8).

The New York City Schools Chess Program included more than 3,000 inner-city children in more than 100 public schools between 1986 and 1990. Based on academic and anecdotal records only, Palm (1990) states that the program has proven:

- Chess dramatically improves a child's ability to think rationally.
- Chess increases cognitive skills.
- Chess improves children's communication skills and aptitude in recognizing patterns, therefore:
- Chess results in higher grades, especially in English and Math studies.
- Chess builds a sense of team spirit while emphasizing the ability of the individual.
- Chess teaches the value of hard work, concentration and commitment.
- Chess instills in young players a sense of self-confidence and self-worth.
- Chess makes a child realize that he or she is responsible for his or her own actions and must accept their consequences.
- Chess teaches children to try their best to win, while accepting defeat with grace.
- Chess provides an intellectual, competitive forum through which children can assert hostility, i.e. "let off steam," in an acceptable way.
- Chess can become a child's most eagerly awaited school activity, dramatically improving attendance.
- Chess allows girls to compete with boys on a non-threatening, socially acceptable plane.
- Chess helps children make friends more easily because it provides an easy, safe forum for gathering and discussion.
- Chess allows students and teachers to view each other in a more sympathetic way.
- Chess, through competition, gives kids a palpable sign of their accomplishments.
- Chess provides children with a concrete, inexpensive and compelling way to rise above the deprivation and self-doubt which are so much a part of their lives (Palm, 1990, pp. 5-7).

A study by Margulies (1993) using a sub-set of the New York City Schools Chess Program produced statistically significant results concluding that chess participation enhances reading performance. A related study, conducted in two U.S. cities over two years, selected two classrooms in each of five schools. The group receiving instruction in chess and logic obtained significantly higher reading scores than the control groups, which received additional classroom instruction in basic education (reading, math or social studies) (Margulies, 1993).

Ferguson (1995) summarizes the findings from the above studies when answering the question, “Why does chess have this impact [on children]?” by listing seven significant factors:

1. Chess accommodates all modality strengths.
2. Chess provides a far greater quantity of problems for practice.
3. Chess offers immediate punishments and rewards for problem solving.
4. Chess creates a pattern or thinking system that, when used faithfully, breeds success.
5. Competition. Competition fosters interest, promotes mental alertness, challenges all students, and elicits the highest levels of achievement.
6. A learning environment organized around games has a positive affect on student’s attitudes toward learning. This affective dimension acts as a facilitator of cognitive achievement. Instructional gaming is one of the most motivational tools in the good teacher’s repertoire. Children love games. Chess motivates them to become willing problem solvers and spend hours quietly immersed in logical thinking. These same young people often cannot sit still for fifteen minutes in the traditional classroom.
7. Chess supplies a variety and quality of problems (Ferguson, 1995, p. 12).

Kennedy (1998) lists 8 related reasons why chess should be included in the classroom:

1. Chess removes barriers between students.
2. Chess gives students at least one reason to come to school.
3. Chess builds rapport between students and adults.
4. Chess honors non-traditional cognitive styles.
5. Chess builds life skills and critical thinking.
6. Chess builds metacognition as students learn to examine their own thinking.
7. Chess integrates different types of thinking.
8. Chess challenges and expands our understanding of intelligence.

An early study took place from 1974 – 1976 in Belgium, where Christiaen found a chess-playing experimental group of 20 fifth graders experienced a statistically significant gain in cognitive development (IQ) over a control group, using Piaget's tests for cognitive development (Ferguson, 1995). The experimental group received 42 hours of chess instruction over the course of one year (sixth grade). Perhaps more noteworthy, they also did significantly better in their regular school testing as well as in standardized testing administered by an outside agency which did not know the identity of the two groups. Quoting Dr. Adriaan de Groot: "In addition, the Belgium study appears to demonstrate that the treatment of the elementary, clear-cut and playful subject matter can have a positive effect on motivation and school achievement generally" (Ferguson, 1995, p. 3). Dullea (1982) believes this study by Dr. Christiaen needs support, extension and confirmation but also that it provides "scientific support for what we have known all along – chess makes kids smarter!"

Statement of the Problem

Given the need to improve critical and creative thinking skills in our young people, would the addition of chess instruction to the curriculum in our nation's schools increase abstract reasoning and problem-solving ability? Although numerous studies and anecdotal evidence over the last 30 years have extolled the benefits of chess, only the 1975 Belgian study by Dr. Christiaen provides evidence of an increase in intellectual maturation. This study seeks to support, extend and confirm Christiaen's work on the effects of chess on abstract reasoning and problem-solving ability in young people by measuring any gains in IQ produced after 20 hours of chess instruction during a one-week time period. More specifically, this study seeks to answer the question: Can chess instruction produce a significant increase in abstract reasoning and problem-solving ability (IQ) in our young people?

Hypotheses

1. Ho: There is no significant increase in intelligence, as measured on a standard intelligence test, between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction.
Ha: There is a significant increase in intelligence, as measured on a standard intelligence test, between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction.
2. Ho: There is no significant increase in chess (or domain-specific) problem-solving ability between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction.
Ha: There is a significant increase in chess (or domain-specific) problem-solving ability between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction.

3. Ho: There is no significant correlation between scores on the Knight's Tour chess problem and IQ scores on the Test Of Non-Verbal Abilities (TONI-3) for elementary school children.

Ha: There is a significant positive correlation between scores on the Knight's Tour chess problem and IQ scores on the TONI-3 for elementary school children.

The first and second hypotheses seek to confirm Christiaen's work on the effects of chess on abstract reasoning and problem-solving ability in young people. The third hypothesis seeks to substantiate the belief that the Knight's Tour is not just an exercise in domain-specific (chess) problem-solving but a valid measure of general abstract reasoning and, hence, intelligence.

Operational Definitions

Anastasi and Urbina (1997) define human *intelligence* as "that combination of cognitive skills and knowledge demanded, fostered, and rewarded by the experiential context within which the individual functions" (pp. 320-321). This is a relatively domain-specific definition. Renowned psychologists like Spearman, Thorndike, Cattell and Piaget, to name a few, have developed their own definitions of intelligence, but there are "commonalities" among these definitions; "in particular the inclusion of the ability to reason, to think abstractly, to perceive relationships, to solve problems, to act with purpose, and to adapt to or cope effectively with the environment (Brown et al., 1997, p.7). This research will operationalize the general definition of intelligence defined by Spearman's g-factor to define human *intelligence*. Brown et al. (1997) states: "Spearman called this [common factor]...that is characteristic of, or that underlies, all intelligent behavior...the g-factor...which Cattell and Horn would identify as cognitive agility, adaptability, originality, and flexibility" (pp. 8-9). The commonalities cited above would be included in this operational definition of intelligence.

The terms *abstract reasoning* and *problem-solving* will be used “to describe processes that are applied to a novel situation in which the solution is not immediately apparent and the problem solver is forced to find a solution among several possible alternatives” (Brown et al., 1997, p. 19, citing Mayer, 1992; Walters & Gardner, 1986).

CHAPTER 2. METHODOLOGY

Participants

The subjects for this study will be elementary school children participating in a one-week chess program in July, 2000 at the Foote School in New Haven, CT. Subjects are self-selected for the program, coming from various elementary schools (both public and private) in the greater New Haven area. There are two chess instructors, one a United States Chess Federation certified chess coach and high school teacher, the other a college student who previously captained the 1997 Connecticut State High School Championship team. Testing will be administered by a qualified diagnostician not associated with the chess instruction.

Instruments

The Test of Non-Verbal Intelligence (TONI-3) was chosen to determine abstract reasoning and problem-solving ability. The TONI is a non-verbal instrument developed in 1982 to assess the intelligence of children and adults whose cognitive, linguistic, or motor skills might adversely affect their performance on traditional intelligence tests. This test is now in its third edition. The test has two equivalent forms (A and B), making it highly suitable for pre- and post-testing. According to the authors, the TONI-3 “clearly evidences a high degree of reliability” (Brown et al., 1997), with an average overall reliability coefficient of .96 across all three types of reliability: test-retest, alternate form, and split-half. However, the alternate form reliability is the lowest at between .79 and .95. Considering that reliability coefficients should “approximate or exceed .80” (Anastasi & Urbina, 1997), the TONI-3 has a high measure of reliability. Test-retest reliability is quite high at .91 for Form A and .92 for Form B (Brown et al., 1997).

Test developers demonstrate the validity of the instrument in three areas: content validity, criterion-related validity, and construct validity (Anastasi & Urbina, 1997). Content validity involves “the systematic examination of the test content to determine whether it covers a representative sample of the behavior domain to be measured” (Anastasi & Urbina, 1997, pp. 114-115). Item analysis, based on a normative sample of 3,451 subjects, was used to refine the third edition of the instrument, and verify its content validity. Criterion-related validity measures “the effectiveness of a test in predicting an individual’s performance in specified activities” (Anastasi & Urbina, 1997, p. 118). Criterion-related validity for the TONI-3 is high, showing correlation coefficients with the WISC-III and WAIS-R in the .70s (Brown et al., 1997). Construct validity measures “the extent to which the test may be said to measure a theoretical construct or trait” (Anastasi & Urbina, 1997 p. 126). According to a study done by the authors, the TONI-3 has a moderately high predictive validity (.71) with academic achievement (Brown et al., 1997). The authors divided the normative sample into subgroups, and mean scores of the subgroups are very supportive of the construct validity of the TONI-3 (Brown et al., 1997, p. 117, Table 7.12).

Based on the above information, the TONI-3 can be considered a valid and reliable measure of intelligence. That fact, coupled with the added advantages of two forms and an average administration time of 15 minutes, made the TONI-3 very suitable to use as a measure of intelligence to test this study’s first hypothesis.

The second instrument used in this study is a chess problem called the Knight’s Tour. It was deemed important to use some domain-specific instrument that might measure the student’s overall chess problem-solving ability. Bagnall (1998) describes the Knight’s Tour problem as follows:

In the knight's tour, one is given the task of finding a route for the chess piece to travel the entire board, landing on each square once and only once, until every square has been visited....The earliest record of the problem is in an Arab manuscript of the ninth century A.D., currently located in the Istanbul library. Later in the Renaissance, mathematicians such as Legendre, De Moivre, Vandermonde, De Montmort, and Euler began to take notice. Euler is reported to have been the first to make the first [sic] serious approach by mathematical analysis, producing a solution in 1757 (pp. 1-2).

Mathematically, the Knight's Tour reduces to a Hamiltonian circuit, or a "closed path that visits each node exactly once" (Stewart, 1997). If the knight begins on its starting square, it can travel to 63 other squares on a standard chess board; however, the problem is relatively difficult to solve, as the knight can get stuck (unable to move to a square it has not previously visited) before completion of the task.

The Knight's Tour can be administered online (<http://enchantedmind.com/knight.htm>). Students are given a chessboard on-screen with the knight on its starting square, and they use the computer mouse to click to squares the knight could visit, eventually trying to fill the entire chessboard. The number of squares they are able to visit before getting stuck is their score, ranging from a possible low of 9 (the least number of squares the knight visits before getting stuck) to a high of 63 (a completed tour). The online format makes administering this task relatively simple and uniquely suitable for measuring domain-specific (chess) problem-solving.

The Knight's Tour, however, is not a valid psychological instrument to measure intelligence, so it can only be used to confirm the second hypothesis in this study. However, a correlation analysis will be performed with the IQ scores from the TONI-3 and the Knight's Tour scores to determine the validity of the Knight's Tour when testing intelligence. The correlation can be used to substantiate the third hypothesis of this study.

Design

The design used in this study is a dependent-samples design. Subjects were not informed about the nature of the study, nor about their scores on the TONI-3 and Knight's Tour. In an effort to make the study double-blind, pre-test and post-test scores were withheld from the researcher until after the chess program was complete; this should also have minimized error variance as the researcher was also one of the instructors in the chess program.

Procedures of Data Collection

Subjects were individually tested at the beginning and at the end of the program by a qualified diagnostician. Testing took place in an isolated environment free from distraction. The diagnostician kept all data confidential until after final testing was complete.

Statistical Analysis

Statistical analysis was performed using SAS. A T-Test for dependent samples was used to test for both TONI-3 scores and Knight's Tour scores. A p-value $< .05$ was deemed significant. The Shapiro-Wilk test for normality and a normal quantile plot were used to determine whether difference scores were normally distributed. In addition, boxplots were used to compare pre-test and post-test data. A correlation analysis using a Pearson correlation coefficient matrix was used to determine correlation between pre-tests and post-tests, and correlation between TONI-3 scores and Knight's Tour scores.

CHAPTER 3. RESULTS

The subjects tested in the study were 19 elementary school children, 15 male and 4 female, ranging in age from 7 to 14 years, with a median age of 8 years old. Fourteen students were Caucasian, 3 were Asian, and 2 were African-American. The students were participating in a one-week chess program in July, 2000, at the Foote School in New Haven, CT. Subjects were self-selected for the program, coming from various elementary schools (both public and private) in the greater New Haven area. There were two chess instructors, one a USCF certified chess coach and high school teacher, the other a college student who previously captained the 1997 Connecticut State High School Championship team. A qualified diagnostician not associated with the chess instruction administered testing. The diagnostician individually tested subjects at the beginning and at the end of the program. Testing took place in an isolated environment free from distraction. The diagnostician kept all data confidential until after final testing was completed (data is presented in Appendix A).

The hypotheses tested were as follows:

1. Ho: There is no significant increase in intelligence, as measured on a standard intelligence test, between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction ().
Ha: There is a significant increase in intelligence, as measured on a standard intelligence test, between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction ().
2. Ho: There is no significant increase in chess (or domain-specific) problem-solving ability between pre-test and post-test scores of elementary school children after a one-week chess program involving 20 hours of instruction ().

Ha: There is a significant increase in chess (or domain-specific) problem-solving ability between pre and post test scores of elementary school children after a one-week chess program involving 20 hours of instruction ().

3. Ho: There is no significant correlation between scores on the Knight's Tour chess problem and IQ scores on the Test Of Non-Verbal Abilities (TONI-3) for elementary school children.

Ha: There is a significant positive correlation between scores on the Knight's Tour chess problem and IQ scores on the TONI-3 for elementary school children.

Statistical analysis was performed using SAS. A T-Test for dependent samples () was used to test for both TONI-3 scores and Knight's Tour scores. A p-value $< .05$ was deemed significant. The Shapiro-Wilk test for normality and a normal quantile plot determined whether scores were normally distributed. In addition, boxplots compared pre-test and post-test data. A correlation analysis using a Pearson correlation coefficient matrix determined correlation between pre-tests and post-tests, and correlation between TONI-3 scores and Knight's Tour scores.

The first hypothesis was confirmed with $p = .02$ (see Table I). There was sufficient evidence to suggest the chess program produced a significant increase in intelligence (see Figure 1 for boxplots of pre-test and post-test scores). In addition, a high correlation between Form A and Form B of the TONI-3 was confirmed from the correlation matrix with $r = .75$ (see Table III). W-Test and normal probability plots showed difference scores to be considered normally distributed (see Appendix B).

The second hypothesis was confirmed with $p < .01$ (see Table II). There was sufficient evidence to suggest the chess program produced a significant increase in domain-specific problem-solving ability (see Figure 2 for boxplots of pre-test and post-test scores). Correlation between pre-tests and post-tests for the Knight's Tour was moderate, with $r = .33$, but not significant (see Table III),.

The third hypothesis was not confirmed. Although correlation between the post-test for IQ and the post-test for the Knight's Tour was moderate with $r = .41$ ($p = .08$), the correlation between the pre-test for IQ and the pre-test for the Knight's Tour was low with $r = .12$ ($p = .63$). There was insufficient evidence to suggest the Knight's Tour is a valid instrument when testing general intelligence (see Table III). In addition, a strong positive linear relationship between pre-test and post-test was found for IQ scores ($p = .0002$). This tends to substantiate the claim of high reliability between the TONI-3 Form A and Form B (Brown et al., 1997). A moderate positive linear relationship was found for Knight's Tour scores ($p = .16$).

Table I
Dependent T-Test for IQ Difference (Post-test – Pre-test) Scores

N	Mean	Std. Error	T	p-value
19	7.1579	2.8961	2.4715	0.0237

Table II
Dependent T-Test for Knight's Tour Difference (Post-test – Pre-test) Scores

N	Mean	Std. Error	T	p-value
19	6.4737	2.1863	2.9610	0.0084

Table III
Correlation Matrix of Pre-test and Post-test IQ and Knight's Tour Scores

	Pre-IQ	Post-IQ	Pre-Knight	Post-Knight
Pre-IQ	1.0000	0.7490	0.1178	0.3110
Post-IQ	0.0000	1.0000	0.2330	0.4069
Pre-Knight		0.0002	1.0000	0.3338
Post-Knight		0.0000	0.0000	1.0000

Post-Knight	1.0000
	0.0000

Note. First value in each cell is the Pearson correlation coefficient and second value is the p-value.

Figure 1. Boxplots comparing pre-test (top) and post-test (bottom) IQ scores.

Figure 2. Boxplots comparing pre-test (top) and post-test (bottom) Knight's Tour scores.

CHAPTER 4. DISCUSSION

Summary and Interpretation

This research confirms and extends earlier work regarding the ability of a chess program to significantly increase levels of abstract reasoning and problem-solving in children. It supports the proposition that overall intelligence in young people is enhanced by chess instruction. Since scores on the TONI-3 have a high correlation with academic achievement (Brown et al., 1997), chess instruction may lead to increased academic success. A chess curriculum taught in our nation's schools would seem to be a beneficial addition to a student's formal education.

Limitations

This study is limited in scope and should be interpreted as part of a growing set of research results. The conclusions drawn must be tempered by the following limitations:

1. The subjects were self-selected, possibly making the sample predisposed to larger potential benefits of chess instruction than a randomly selected group might be. Thus, the study suffers to some degree from undercoverage.
2. The sample size was relatively small. Even though scores tended to be normally distributed, a larger sample would make the study more comprehensive, producing more reliable results. Until chess becomes prevalent in our nation's school systems, studies of this type will tend to attract small, self-selected groups of students. Under these circumstances, a dependent design has advantages over an independent design since it increases the relative sample size of the treatment group, allowing the limited number of subjects to act as their own controls.
3. The question that immediately comes to mind is, "Given the favorable results, can these increases in intelligence be sustained?" The study suffered because the nature of the chess program prohibited a time series design, which would go far in answering this question. The researcher did not have access to testing subjects at time intervals before and after the program, which would possibly have increased the validity of the study's findings.
4. The short duration of the chess instruction (20 hours over a one-week time period) would tend to minimize the significance of a chess program's effectiveness in raising IQ scores. This was a major concern from the outset. However, the fact that significant gains were achieved in spite of the short duration of the program only strengthens the conclusion that chess instruction can be effective in elevating intelligence levels.

Recommendations

The present study substantiates the growing body of evidence that suggests chess can be instrumental in developing higher levels of intelligence in students, which in turn could lead to academic success. Since increased abstract reasoning and problem-solving are only two of the myriad benefits chess offers students, a comprehensive chess curriculum should be adopted by our schools. Ultimately, the practical goal of this study is to provide a suggestion for producing higher achievement among our students in an effort to create a more productive and responsible citizenry. The inclusion of a chess program at the elementary and high school levels can only benefit our students and will go a long way in helping make these goals attainable. As this research suggests, chess may even make students smarter.

Suggestions for Further Research

A time series study over a year or longer would help substantiate the findings of this research and increase reliability. An important continuation would involve the determination of whether or not the increases found in the present study are sustainable. Furthermore, as the students in our sample seemed to be of average or above average ability, examining the effects of a chess program on under-achievers is necessary to make these findings more comprehensive. Future research may seek to address the effects a chess program might have on the acquisition of social skills as well as whether there is any cultural, racial, age or gender-related bias to the effects. It is my hope that educators will recognize the importance of on-going research on chess instruction and increase the visibility of chess in the schools in an effort to facilitate funding and makes larger samples for research more readily available.

APPENDICES

APPENDIX A

DATASET OF PRE- AND POST-IQ AND KNIGHT'S TOUR SCORES

APPENDIX B

DESCRIPTIVE STATISTICS AND NORMALITY PLOTS

APPENDIX C

SAS PROGRAM

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