Chess is an exercise of infinite possibilities for the mind, one which develops mental abilities used throughout life: concentration, critical thinking, abstract reasoning, problem solving, pattern recognition, strategic planning, creativity, analysis, synthesis, and evaluation, to name a few. Chess can be used very effectively as a tool to teach problem solving and abstract reasoning. Learning how to solve a problem is more important than learning the solution to any particular problem. Through chess, we learn how to analyze a situation by focusing on important factors and by eliminating distractions. We learn to devise creative solutions and put a plan into action. Chess works because it is self-motivating. The game has fascinated humans for almost 2000 years, and the goals of attack and defense, culminating in checkmate, inspire us to dig deep into our mental reserves.

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 people in history made chess their favorite pastime. The game's fascination was embraced by Queen Isabella and King Ferdinand of Spain, 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, 1776). 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:

- Chess increases strategic thinking skills, stimulates intellectual creativity, and improves problem-solving ability while raising self-esteem;
- When youngsters play chess they must call upon higher-order thinking skills, analyze actions and consequences, and visualize future possibilities;
- 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:

- Chess accommodates all modality strengths.

- Chess provides a far greater quantity of problems for practice.
- Chess offers immediate punishments and rewards for problem solving.
- Chess creates a pattern or thinking system that, when used faithfully, breeds success.
- Competition. Competition fosters interest, promotes mental alertness, challenges all students, and elicits the highest levels of achievement.
- 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.
- 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.

The earliest study, produced in 1975, took place 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 provides "scientific support for what we have known all along – chess makes kids smarter!"

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 (Celone, 2001). This extends and confirms earlier work done in 1975 by Christiaen in Belgium.

References

Artise, J. (1973). Chess and Education. (Article No. 4) United States Chess Federation Scholastic Department.

Anastasi, A. & Urbina, S. (1997). Psychological Testing (7th ed.). Upper Saddle River, NJ: Prentice-Hall, Inc.

Bagnall, W. (1998). The Knight's Tour. [Online].

Available:http://www.zoomnet/~wbagnall/kttour.html
Bell, T. (1982). Your Child's Intellect. Salt Lake City: T. Bell and Associates.
Bloom, B. S. (1956). Taxonomy of Educational Objectives: The Classification of Educational Goals. New York: Longmans, Green, and Co.
Brown, L., Sherbenou, R., & Johnsen, S. (1997). TONI-3: Test of Nonverbal Intelligence Examiner's Manual (3rd ed.). Austin, TX: PRO-ED Inc.
Celone, James. (2001) The Effects of a Chess Program on Abstract Reasoning and Problem-Solving in Elementary School Children Ann Arbor, MI. Bell & Howell Information and Learning Co.
Drummond, T. (2000, February). Harlem's chess kings. Time, 155, 8.
Dullea, G. (1982, November). Chess makes kids smarter. Chess Life, 37, 18.
Ferguson, R. (1983, Fall). Teaching the fourth r (reasoning) through chess. School Mates Chess Coach Newsletter, 3.
Ferguson, R. (1995). Chess in education research summary. Paper presented at the BMCC Chess in Education "A Wise Move" Conference, New York, NY.
Franklin, B. (1786). The Morals of Chess. [Online]. Available: http://personal.wofford.edu/~kaycd/CHESS-GO/bf-moral.htm
Graham, A. (1985, December). Chess makes kids smart. Parents, 113-116
Hall, R. (1983). Why chess in the schools. Oregon City, OR. (ERIC Reproduction Service No. ED 237368)
Horgan, D., & Morgan, D. (1986). Chess and education. Memphis State University, Memphis, TN. (ERIC Reproduction Service No. ED 275408)
Horgan, D., Horgan, T., & Morgan, D. (1986, April). Abstract schemas in children's chess cognition. Paper presented at the Conference on Human Development, Nashville, TN.
Horgan, D., (1987). Chess as a way to teach thinking. (Article No. 11) United States Chess Federation Scholastic Department.
Horgan, D., (1988). Where experts come from. Paper presented at the Annual Meeting of the Decision Sciences Institute, Lincoln, NE.
Horgan, D., & Morgan, D. (1988, August). Experience, spatial abilities, and chess skill. Paper presented at the Annual Meeting of the American Psychological Association, Atlanta, GA.
Kennedy, M. (1998). More than a game: Eight transition lessons chess teaches. Reaching Today's Youth: The Community Circle of Caring Journal, 2, 17-19.
Knight's Tour. [Online]. Available: http://enchantedmind.com/knight.htm
Lasker, E. (1949). The Adventure of Chess. Garden City, NY: The Country Life Press.
Liptrap, J. (1997). Chess and standardized test scores. Chess Coach Newsletter, 11, 5-7.
Margulies, S. (1993). The effect of chess on reading scores: District nine chess program second year report. (Article No. 5) United States Chess Federation Scholastic Department.
Math and Chess Learning Center. Welcome to the math and chess puzzle center. [Online]. Available: http://www3.bc.sympatico.ca/mathchess/
Milat, M. (1997). The role of chess in modern education. [Online]. Available: http://www.chess.bc.ca/marcel2.html.
Palm, C. (1990). Chess improves academic performance. . (Article No. 2) United States Chess Federation Scholastic Department.
Rifner, P., & Feldhausen, J. (1997). Checkmate: Capturing gifted student's logical thinking using chess. Gifted Child Today Magazine, 20, 36-39, 48.
Schmidt, B. (1982). How to teach chess in the public schools: A course outline. Raleigh, NC: Author.
Schneider, W., Gruber, H., Gold, A., & Opwis, K. (1993). Chess expertise and memory for chess positions in children and adults. Journal of Experimental Child Psychology, 56, 328-349.
Smith, J., & Sullivan, M. (1997, November). The effects of chess instruction on students' level of field dependence/independence. Paper presented at the Annual Meeting of the Mid-South Educational Research Association, Memphis, TN.

Stewart, I. (1997, April). Knight's tours. Scientific American, 276, 102-104.
Vail, K. (1995). Check this, mate: Chess moves kids. The American School Board Journal, 182, 38-40.
Whitman, N. (1975, January). Chess in the geometry classroom. Mathematics Teacher, 68, 71-72.
Wojcio, M. (1990). The importance of chess in the classroom. (Article No. 3) United States Chess Federation Scholastic Department.
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