Chess Instruction to Improve Algorithmic Computation Skills, Mathematics, and Life

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Description of the Topic

"Much has been said of the affinity between mathematics and chess: two domains of human thought where very limited sets of rules yield inexhaustible depths, challenges frustration and beauty"(Elkies & Stanley, 2003, 22). The challenge that will be discussed in this paper is the ability to use chess to help developmental mathematics students improve their skills in mathematics as well as perform algorithmic computations. "Mathematics as an expression of the human mind reflects the active will, the contemplative reason, and the desire for aesthetic perfection. Its basic elements are logic and intuition, analysis and construction, generality and individuality. Though different traditions may emphasize different aspects, it is only the interplay of these antithetic forces and the struggle for their synthesis that constitute the life, usefulness, and supreme value of mathematical science (Diaz, 1). "Math provides the building blocks and foundations that children will need throughout their lives" (Deb, 1). The life value of mathematics often is still very small for developmental mathematics; therefore, they fail to recognize the importance of performing algorithmic computations in mathematics. These computations are also used in the workplace. Teachers must emphasize the connection between mathematics and work. "The basic skills needed to function in the workplace today are decision making, problem-solving, critical thinking and deductive and inductive reasoning along with the ability to make judgments and good estimates" (Deb, 1)

The life value in chess has been recognized for years. "A chess game is a war between two medieval kingdoms. In medieval times, when Kingdoms were small, absolute monarchies, if the King was imprisoned or captured, the war was over. So it is in the game of chess. The game is finished when one of the Kings is captured. It may here be noted that Chess is not necessarily a game of elimination, but rather a game of tactics. However, elimination of the opponent's pieces plays an important part since by so weakening or wearing down your opponent, the game has hastened. A general definition is given by Mason: Chess is a process of thought conditioned and limited by the institutes and rules of the game. The judgments of thought are certified or visibly expressed upon the chessboard in movements of various forces" (Diaz, 2).

Chess players, as for developmental math students, are required to know steps needed to win a game in a certain time period. Time pressure is a very important component of both chess and mathematics. Tournament chess games and mathematics tests have "a fixed limit which adds to the requirements of rigorous concentration and self-discipline"(Hall, 6). In tournament chess, players need to apply the common algorithms of chess quickly or the game may be lost regardless of the position of the pieces on the chessboard. In other words, if a player knows the algorithm (sequence of moves necessary to obtain a positional or material advantage) and knows when to apply it, this becomes irrelevant if the player takes too long to apply the algorithm. If a player runs out of time, the player loses (unless the opposing player does not have the material necessary to win). Similarly, when a student is given a math test, it is timed and students are given a grade only based off of what they have shown on the test. If a student takes too long to use an algorithm, the student may not be given time to complete other problems on the test. The amount of time given in a chess game is critical in determining how the game is played. A game may last anywhere from 2 minutes up to 6 hours. Shorter games require that players have memorized many different types of algorithms and must be able to apply them very quickly. Longer games require that players take time to memorize and apply more complicated algorithms. When students have a small amount of time to complete exams, students have to be able to apply these algorithms quickly in order to make time to complete all problems. Unfortunately, students tend to rush and make careless mistakes if they are given less time to complete a test. If students are given a lot of time to complete tests, professors usually will require students to know more algorithms or more complicated algorithms. Students are given more opportunity to take time to go over their mistakes. Even when students are given more time, they still will need a plan as to how they will go about completing a test. Students are often told to do the easy problems first (those that may require few algorithmic computations) and then do the harder problems (those that may require more complex algorithmic calculations) last.

Planning is very important for all mathematics students. This planning becomes especially important for math tests since they usually have a very large impact on a student's performance. Students ordinarily have a plan prior to beginning a math test. Students must decide which questions they should work on to begin the test. This may be determined by the difficulty of the questions or the amount of points each question is worth. If students do not preview their tests, the original plan of completing all questions on a test timely and accurately may not be accomplished.

Planning often depends on previous knowledge of skills. These skills are reinforced by constant practice. Effective planning may be interrupted when students are not confident in applying the skills that are required for a particular test. Students may tend to guess or speculate what answers should be instead of applying known skills. Plans which are made students to complete tests must be examined thoroughly. Each question (which involves its own individualized plan) completed by the student should be reviewed to minimize careless mistakes. Often times, students make so many careless mistakes that their acquisition of skills may be unrecognized.

There are many similarities between planning for math tests and planning for tournament chess games. Plans made in a game by a chess player are also dependent on previous knowledge. A stronger chess player will consider many more ideas than a novice chess player; therefore, the stronger player tends to have more effective plans. Where performance on math tests depends on the value of the questions which are answered correctly, performance in chess games depends in most cases on the value of the pieces of the player and his or her opponent. The values of these pieces are directly related to the power of the pieces. The more powerful pieces a player has, the more likely it is for that player to win the game. If students do not have confidence in their prior chess skills, it will be difficult to create any effective plans since they may not be sure enough of the possible outcomes. Many games in chess are lost when students don’t review their plans. This is due to the fact that there may be a flaw in the plan. Several moves usually must be considered for a plan in chess to go through. If one move is not considered, the game may end instantly. A goal for many novice chess player is simply to minimize mistakes that are easily fixable. Chess grandmaster Peter Kurzdorfer in his book "The Tao of Chess: 200 Principles to Transform your Game and Your Life" discusses some of the key ideas when considering planning in chess. The following three principles of planning in chess are also related to planning in mathematics.

A bad plan is better than no plan at all. In chess, all moves should be made with a purpose. An overall bad plan can possibly include some smaller plans that may be good plans. Moving pieces without a plan will prove that a chess game can quickly fall apart. When students complete math tests, there needs to be some plan about how the test should be completed. Not having a plan to complete math tests could lead to failure.

A good plan incorporates many little plans. The overall goal in chess is to checkmate your opponent. This plan often involves three smaller plans: an opening plan, a middlegame plan, and an endgame plan. A flaw in one of these smaller plans may affect a good overall plan in its entirety. On a mathematics test, the obvious overall plan is to get 100% of the questions correct. This plan involves successful mini-plans for each individual question. Obviously, a mistake in one of the mini-plans will destroy the overall plan of getting 100% of the questions correct.

Keep your plans flexible. Since plans in chess practically change with every move, it is very important that a player's plan is flexible. More options in your plans in chess allow for more choices. When incorporating plans to answer mathematics questions, one skill may apply to many different questions. When a student has mastered a skill (especially for word problems), that student can apply that skill for many different mathematical applications.

Purpose of the Paper

The purpose of this paper is to explore whether chess instruction will improve the abilities of developmental mathematics students to improve math skills and toperform algorithmic computations. This poses the question of incorporating chess instruction into school curriculums. Many students in developmental mathematics strongly dislike mathematics because of the number of steps necessary to get a solution. A chess player is not bothered by making a lot of moves to arrive at a solution (checkmate or a positional or material advantage). As a result, chess players are likely to have more experience using algorithms to arrive at the desired solution. The great chess players remember several positions (the given algorithm). They often make moves that can bring the chess pieces to one of these “familiar” positions. Similarly, beginning algebra (a developmental math course) students try to do steps that make unrecognizable and complex equations into those that are “familiar”. “Mathematical thinking is generally held to be more or less closely related to the type of thinking done in chess” (Celone).

Definitions

An algorithm (algorithmic computations) is a step-by-step problem solving procedure, especially an established recursive computational procedure for solving a problem in a finite number of steps. Developmental mathematics courses for this study will include Basic Mathematics, Pre-Algebra, Introductory Algebra, and Intermediate Algebra.

Audience

Schools and universities would take an interest in this paper because of the poor performances of developmental mathematics students. Teaching chess in school may improve performance in mathematics. Since students that play chess actually like the game, there may be more motivation from developmental math students to work using algorithms in chess than in mathematics. This paper can be used at any school that offers mathematics at any level.

Literature Review

The Connection Between Chess and the Mathematical Content Standards

The first piece of literature reviewed was a commentary about implementing chess into the mathematics curriculum. The reason why this teacher decided to implement chess into the mathematics curriculum is because he felt that chess would improve mathematical reasoning skills. This teacher, while teaching chess in the classroom, continued to follow his state's Mathematical Content Standards. The teacher was aware that chess instruction might require a significant amount of time. If chess instruction is included to help developmental mathematics students, it will be under debate as to what parts of the math curriculum the chess instruction will replace.

One of the Standards of the Mathematical Content Standards is sequencing and prioritizing information and observing patterns. This is a very important skill for performing algorithmic computations. Prior to students performing an algorithm, the student must have all of the necessary information. Without the correct information, students will not be able to effectively use the algorithm. It is also important that the correct information is used in the correct order. For example, when using order of operations, one should always multiply before subtracting. When performing algorithms, students should recognize patterns. Generally, students understand the need for a common algorithm after they recognize familiar patterns in the numbers used.

Successful chess players also implement these standards. “Chess skill depends to a great extent on pattern recognition and on conditional knowledge” (Rifner). These chess players prioritize information by choosing from a set of familiar openings learned from watching other chess games, reading chess books, or watching instructional videos. When the player decides upon an opening, the opening requires moves to be made in a certain sequence (the opening may have a different name if moves are made out of order which may require different types of instruction). Players may adjust their openings if an opponent makes moves not included in a player’s review of his or her opening. Adjustments are made if an opponent makes the same moves in a different order. Rifner states in teaching chess that “our instruction begins a problem-solving approach designed to give students a systematic method of gathering information from the board and making decisions with that information. He further states that “he or she is ready to use the problem-solving model to set and prioritize goals, analyze possible consequences, develop alternative plans, and evaluate possible courses of action." This illustrates that the skills used to teach chess are similar to the skills that teachers are to teach mathematics students according to the math content standards.

"Two additional standards were (1) determining when and how to break up a problem into simpler parts and (2) applying results from simpler problems into more complex problems"(Peterson, 2002, 64). In order to apply certain algorithms in developmental mathematics, a problem must be written a certain way before a student can apply the algorithm. This may require students to break a problem down into a simpler problem so that students can apply the algorithm. Without breaking the problem down, students may not be able to see from the larger problem the proper algorithm to use. Once students correctly use the algorithm, it is important that students understand the algorithm well enough to apply it to a new problem.

Chess players also use these standards when performing algorithms. The problems that a chess player has often are determining what sequences of moves need to be made by the player and his or her opponent in order to gain a positional or material advantage. If an opponent makes a move that strongly benefits a player, the problem is broken down for the player. When chess players see how to gain these advantages, they must recognize the sequence of moves made as well as the position of the pieces. If more pieces are on the chess board in a similar game, the player must still be able to recognize that the algorithm used to gain that material or positional advantage can still be applied although more pieces may make the algorithm more complex.

Chess in Connection with NCTM Standards

As with other studies I have reviewed, this study also connects chess with curriculum standards. The standards used in this article were the National Council of Teachers of Mathematics. Many teachers believe that developmental math students have struggled in mathematics as far back as elementary school. The author in this article stresses the need of problem solving in mathematics. Students in developmental mathematics classes tend to struggle in the area of problem solving.

This struggle begins when math students have been familiar with the mathematics that they were taught, but forget almost all of the mathematics that they have learned in high school. As a result, they are often taught as if they have no mathematics skills at all. Teaching chess to people who know nothing about chess follows similar methods as teaching developmental mathematics. The following tips are used in the article “Teaching Chess to Young Children”: (1) Start small, (2) play minigames, (3) model your own problem-solving skills and point out the advantages and disadvantages of your own moves. (4) allow do-overs, and (5) listen to the children (Bankauskas, 34). It is natural for teachers to start with the simplest problems (those that involve few algorithmic steps). The algorithms should become more complex only after students have mastered understanding of the small problems. Playing minigames in chess (using just a few familiar pieces) is similar to taking textbook problems (perhaps unfamiliar to students) and rewriting them into problems that students are more familiar with. Modeling problems that students can relate to real-life is very important in developmental mathematics. Several of these students don't realize why mathematics is used in the real world. Students can also learn why using common sense can eliminate answers students obtain through careless errors. Do-overs are used often in developmental mathematics because of the high probability of these errors. Students often are given several practice problems in order to continuously practice these algorithmic computations. Through listening, professors get a better idea as to why careless errors are being made as well as possible misunderstanding of given algorithms. In my classes, developmental math students are required to write journals to communicate to me how they feel about mathematics and feedback is given to the students as to what they can do to improve their mathematical abilities. Through playing chess, their (the children) problem-solving and logical thinking skills flourished (Bankauskas, 34)

Optimism about the Game of Chess

Peterson(2002), a third grade teacher at El Toro School in Morgan Hill, CA, states that his 33 kids were very optimistic about playing chess. He made the connection between chess and math by teaching chess immediately after teaching math. The parents were also optimistic about students playing chess. It is not stated in the article if other classes in this school incorporated chess into the classroom. It also does not state if the teacher knew how to play chess prior to implementing the plan of including chess in the curriculum. It is important to know if this implementation of chess is working effectively from other classes in the school as well. If a teacher does not know how to play chess, this fact is likely to determine if a teacher will decide to implement chess in the classroom.

A Summary of Chess Research

It has been shown through research that chess can be a factor in improving test scores in both the mathematics and education fields. The following article

is a summary of chess research by Dr. Robert Ferguson Jr. (executive director of the American Chess School. These test scores often apply for students of all ages.

The first study summarized by Dr. Ferguson was in Zaire and conducted by Dr. Albert Frank. The study included 92 students, 16-18 years of age, equally distributed at random into a control and experimental group. It was very interesting that the students were chosen from a humanities class. It did not state in the article if there was significance in choosing a humanities class as opposed to a different subject. The result of the study was that "chess significantly improved spatial aptitude, perceptive speed, reasoning, creativity, and general intelligence (Ferguson).

It is recommended in the summary that chess should be included in the curriculum of secondary schools. Along with the abilities previously stated, chess also improved the development of the students' verbal and numerical aptitudes after just one year of study. It is important to note that the way the chess instruction is introduced and the qualifications and experiences of the teacher is likely to play a significant role in improving these aptitudes.

A second study in the summary used 40 fifth grade students who were equally divided randomly into an experimental and control group. The experimental group received 42 one-hour lessons using a chess textbook for youths. The study, directed by Johan Christiaen in Belgium, wanted to determine if chess promoted intellectual maturation. Obviously, intellectual maturation is crucial for developmental mathematics students since they generally have a weak mathematical background and poor study skills. The maturation would play an important role in helping students become better "mathematics students". The tests that were given in the study at the end of the fifth grade and at the end of the sixth grade were Piaget's tests for cognitive development. The results of the tests (chess does improve intellectual maturation) at the end of the 5^{th} grade were significant at the .01 level (there is only a 1% probability that the effects observed are due to chance). The results of the tests at the end of the 6^{th} grade were significant at the .05 level.

The Mathematical Knight

This article by Elkies and Stanley (2003) looks at mathematical applications of the movement of the knight. The article includes several chess puzzles that use mathematical formulas to solve. Although the puzzles use mathematics that is beyond the level of understanding of the average developmental mathematics student, these students can see how one arrives at the solution by using algebraic notation. Algebraic notation relates to mathematics in that it uses the coordinate system to name squares of the board. The puzzles increase in complexity by analyzing the knight's tour over chess boards that are not 8x8. This article appears to be addressed for students who have taken upper-lever mathematics and have years of chess experience. The authors are also very knowledgeable in mathematics. These authors are Elkies from Harvard and Stanley from MIT. The author from Harvard is the youngest ever to get tenure there (age 26).

We may look at the developmental mathematics topic of graphing and make a comparison with a chessboard and the first quadrant of a coordinate plane. A chessboard is comprised of an 8 x 8 square containing 64 smaller squares. Therefore, we may consider a coordinate plane in the first quadrant considering 8 units on the x-axis and 8 units on the y-axis. Students may then locate pieces on the chessboard by considering each square of the chessboard as an ordered pair. The lower-left corner of the chessboard (a black square) would be given the ordered pair (1,1). The upper-right corner of the chessboard would be given the ordered pair (8,8). A developmental math student can be asked to find the ordered pairs of each piece to begin a chess game (or during the middle of a game). At the beginning of a chess game, the two white rooks have the ordered pairs (1,1) and (8,1), the two white knights have the ordered pairs (2,1) and (7,1), the two white bishops have the ordered pairs (3,1) and (6,1), the white queen has the ordered pair (4,1), the white king has the ordered pair (5,1), and the eight white pawns have the ordered pairs (2, m) where m goes from 1 through 8. Students can then find the ordered pairs of the black pieces using previous information about the locations of the white pieces.

The most complicated piece to understand in chess is the Knight. The Knight's tour on the chessboard can also be demonstrated using a mathematical approach. If we just look at the movement of the Knight only, we can compare its movement to the slope. The slopes (which we will consider as y/x or rise/run) related to knight's tour are 1/2,

-1/2, 2/1, and -2/1. For example, if a Knight begins at the location (4,4), there are eight new locations for the Knight's next move. These new ordered pairs are (3,6), (5,6), (6,5), (6,3), (5,2), (3,2), (2,3), and (2,5). Keep in mind that the four slopes can be rewritten as

-1/-2, 1/-2, -2/-1, and 2/-1, respectively. In a chess game, one must be able to plan as to where the Knight (or any other piece) can be relocated on its next move. This is similar to mathematics in that the slopes for equations of lines are used to locate points for the future. Looking at mathematics word problems (a great struggle for developmental math students), students must understand that there will be constraints in word problems. If one considers an employee's gross pay as a function of the number of hours worked, say y = 10x, some ordered pairs of the graph of y = 10x would not be considered. These ordered pairs would be those that the x or y coordinate was negative. Movements of the knight as well as other chess pieces also have limitations in their movements depending on their location on the chessboard. For example, a knight located at (2,7) cannot move using the slopes 2/1, 2/-1, 1/-2, or –1/-2 since the knight would no longer be on the chessboard.

Ho Math and Chess

Ho Math and Chess is the first franchise known to integrate chess into mathematics as well as the first creator of mathematics and chess workbooks. This idea was created by Frank Ho in 1995 in Vancouver, Canada. There are other Ho Math and Chess Tutoring Centers throughout the world. The following statement was taken from the website demonstrating that the increase in mathematics scores on a standardized test through instruction at these franchises was statistically significant.

Note: These results just in after 60 hours of math tutoring in the 2006-2007 Chess Academy Math Tutoring Program with a group of 119 students. The average gain per student was 19% on a standardized mathematics test.

Paired t *test results*

P value and statistical significance:

The two-tailed P value is less than 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.

Confidence interval:

The mean of Group One minus Group Two equals -18.98
95% confidence interval of this difference: From -21.90 to -16.06

Intermediate values used in calculations:

t = 12.8729
df = 118
standard error of difference = 1.475

While both math and chess are universally considered to be boring and repetitive,

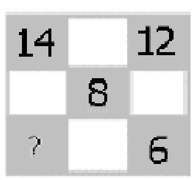
workbooks used by franchisees of Ho Math and Chess make math and chess creative and

fun.

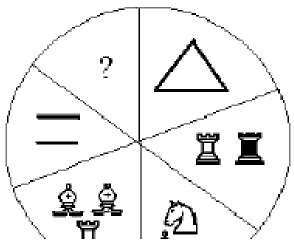
The workbooks are also useful for ADD/ADHD students. The workbooks keep the attention of these students through puzzles. These puzzles include a lot of visual images and require students to “hunt and create” which stimulates their interests. Through the Kinder and Junior Magic Chess and Fun Math Puzzles, students work on the following: (1) Master math basics skills in the subjects of basic arithmetic operations, symmetry, number relations, logic, spatial relation, symbols, image processing, patterns and sequence, comparisons, set theory, multi-step puzzles etc. (2) Learn the basics of chess. (3) Learn problem-solving techniques using chess and math integrated problems. (4) Learn the skills on how to solve mathematical chess puzzles.

Here are a few examples taken from Ho's website www.mathandchess.com.

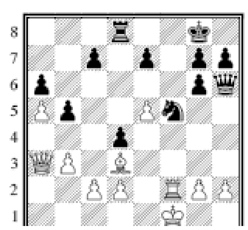
Addition

Math Puzzle Samples	Expected Math Learning Outcomes	Chess Knowledge Required
Replace each? with a number. 	▪ Adding numbers ▪ Multi-direction operation	▪ Bishop move
	▪ Addition ▪ Comparison	▪ Value of chess pieces

Geometry

Chess Puzzle Samples	Expected Math Learning Outcomes	Chess knowledge required
Find answer to replace the question mark. 	▪ Geometry	▪ Chess pieces moves

Cancellation

Chess Puzzle Samples	Expected Math Learning Outcomes	Chess Knowledge Required
The way to see which side has more points is not to add up all the total points of chess pieces of each side. Find out which side has more points by cancellation. Cancel pawn with pawn and the same chess piece (or the same number of points) of each side. 	The idea of one-to-one cancellation of chess pieces left on the board is similar to the subtraction property of equation. Evaluate the following. $\frac{1}{2}\times\frac{2}{4}\times\frac{4}{6}\times\frac{6}{8}\times\frac{8}{10}\times\frac{10}{12}$ Do not multiply numbers together first. Cancel numbers whenever you can by having a pair of numerator and denominator divided by the same number.	▪ Value of chess pieces

Research Results

It is essential that critics see that there are numerous research studies which show that chess instruction does improve mathematical achievement. The research has been done all around the world with a variety of grade levels. These results demonstrate what many people speculate about chess.

Improvement in chess through chess instruction can make significant difference in student performance.

Both mathematics students and chess players rely on memorization. Chess players memorize openings and mathematics students are required to remember formulas (sometimes even formulas from previous math courses). Having a great memory as a chess player or as a mathematics student is a definite advantage, but is clearly a disadvantage if either the chess player or the math student solely relies on memory to be successful. An overemphasis in memorization leads to a lack of understanding. Some math students now have a poor mathematical foundation on the college level since a student can no longer be successful without true understanding. A chess player will not be successful if he or she memorizes opening moves, but does not understand the purpose of the moves. In many cases, the chess player and the math student should expect the unexpected. However, memory is required to show understanding of additional mathematical concepts. Practically all chess grandmasters have memorized several openings. In his research summary on “Chess and Education”, he notes from John Artise that “Visual stimuli tend to improve memory more than any other stimuli; … chess is definitely an excellent memory exerciser the effects of which are transferable to other subjects where memory is necessary” (Ferguson). Ferguson wanted to prove that memory can improve through chess instruction. The dependent variables in this study were the Test of Cognitive Skills(TCS) and the Verbal Reasoning subtest from the California Achievement Tests Battery. The differences from the pre and posttests were measured significantly using the t test of significance. All but one student showed an increase from the pre to the posttest after chess instruction. The results are listed below:

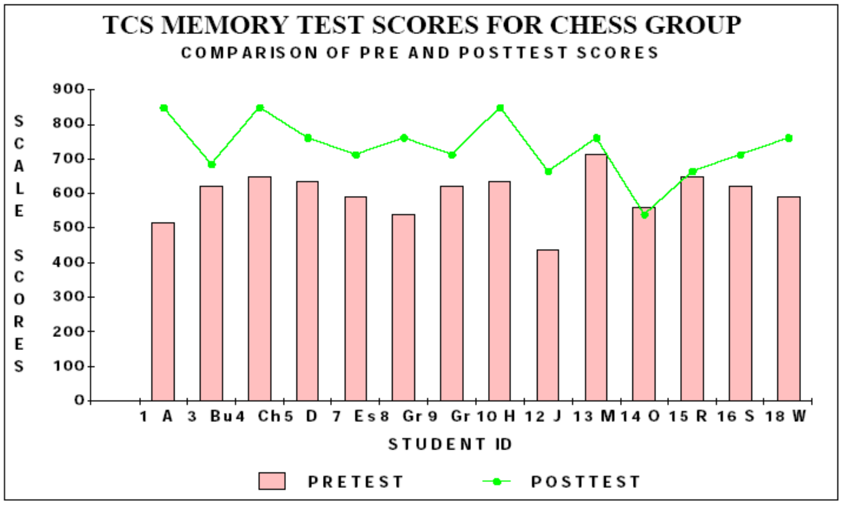


FIGURE 1. Comparison of pretest and posttest scores on the *TCS* Memory test

TABLE A. Dependent t test evaluating significance of gains on the *TCS* Memory test by chess players

VARIABLE	**NUMBER**	**MEAN**
Pretest Scores	14	597.786
Posttest Scores	14	727.786
Difference	**Standard Error**	**t value**
130	24.86	5.23

Significant beyond the .001 level

2

Listed below are some of the most well-known results that show the effects of chess instruction on mathematics achievement given in Robert

Ferguson's Research Summary. The research shows that chess improves many other skills, but this paper will primarily focus on those pertaining to mathematics.

In a 1977-1979 study at the Chinese University in Hong Kong by Dr. Yee Wang Fung, chess players showed a 15% improvement in math and science test scores.

During the 1987-88 ``Development of Reasoning and Memory through Chess," all students in a rural Pennsylvania sixth grade self-contained classroom were required to participate in chess lessons and play games. None of the pupils had previously played chess. The pupils significantly improved in both memory and verbal reasoning. The effect of the magnitude of the results is strong (eta 2 is .715 for the Memory test gain compared to the Norm). These results suggest that transfer of the skills fostered through the chess curriculum did occur.

A 1989-92 New Brunswick, Canada study, using 437 fifth graders split into three groups, experimenting with the addition of chess to the math curriculum, found increased gains in math problem-solving and comprehension proportionate to the amount of chess in the curriculum.

In a 1994-97 Texas study, regular (non-honors) elementary students who participated in a school chess club showed twice the improvement of non-chess players in Reading and Mathematics between third and fifth grades on the Texas Assessment of Academic Skills.

Chess Education

“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 (Celone). There are several schools that offer chess as courses for credit. In fact, the state of New Jersey passed Bill #S452 legitimizing chess as a unit of instruction. An excerpt from the bill reads: 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;

These schools believe that chess offers benefits that may not necessarily be seen on college transcripts or academic report cards. These are a few schools, universities, and programs that offer chess as a course.

The mission of Chess-in-the-Schools is to improve academic performance and build self-esteem for inner city school children. Each third-grade classroom and sixth-grade classroom in participating elementary and junior high schools is assigned a Chess-in-the-Schools trained instructor. The instructor teaches an hour-long chess lesson once a week in five classrooms during the school day in the fall semester, and in five different classrooms in the spring semester. Each instructor teaches 250 to 300 students in each school during the year. Lessons are scheduled on the same day and time each week, and classroom teachers often remark that attendance is highest on “chess day.” Chess-in-the-Schools provides all the materials needed to learn and play chess, including a chess set and Chess-in-the-Schools workbook for each child to keep. In addition, each participating classroom receives chess sets.

There are over 10 schools in Connecticut that offer chess as courses. Many of the chess courses are ran by certified chess coach Jim Celone. He currently teaches AP Calculus and AP Statistics at West Haven High School. He is a USCF Certified Chess Coach and Tournament Director, vice president of the CT State Chess Association, and coaches the chess team at West Haven High School, winning the Connecticut State Championship eight different years. He was honored as 2002 CT Chess Coach of the Year.

The Daviess County Public School’s Graduation 2010 is a 13 year program whose purpose is to help children excel in the learning process. Kindergarden students (1997-1998) are expected to all graduate in 2010. The components of the program are: the arts, music, foreign language, reading, critical thinking, health and emotional health, parental involvement, and community involvement. The game of chess was to be used each year to improve the critical thinking skills of these students. These critical thinking skills will likely improve the math skills of these students. “Teaching a child to play chess at an early age engages the neurons in the portion of the brain responsible for Math/Logic” (Englehardt,6) Englehardt used a manual which she created, Teaching Chess in the Elementary Grades, which is recommended as a five-year curriculum plan. As with mathematics, the material learned for a given year builds upon what was learned the previous year and the curriculum takes students from simple concepts to the more complex topics. The goal of the five-year plan was as follows:

1) To enhance critical thinking skills in students at an early age
2) To ensure a scope and sequence chess curriculum between grade levels
3) To give direction and add simplicity to lesson planning
4) To minimize classroom management
5) To teach all students the basic fundamentals of the game of chess.

The University of Texas at Dallas offers several chess courses for graduate and undergraduate students. The courses are taught by Dr. Alexey Root, author of Children and Chess: A Guide for Educators. The University of Texas at Dallas is one of the top universities known for chess. High school students who excel at chess are eligible to receive full scholarships to attend school at the university. Listed below are course descriptions of the four courses offered at the University of Texas at Dallas:

ED 4358: Chess I - Using Chess in Elementary Schools (undergraduate)

3 semester hours. This course provides a curriculum development model for chess. In this model, humanistic and academic goals for learners are

addressed through chess. For learners, chess enables experiences of flow and competition. Chess may help develop an internal locus of control. By tapping into visual-spatial intelligence, chess makes accessible hierarchical reading and math concepts. Chess exemplifies how people solve problems.

ED 5344: Chess I - Chess in the Elementary School Curriculum (graduate)

3 semester hours. A consideration of methods for using chess to teach problem solving, math, and reading skills in the elementary classroom, based upon the curricular model developed by McNeil.

ED4359: Chess II - Using Institutional & Cultural Contexts of Chess (Undergraduate)

Chess in the Classroom II: Institutional and Cultural Contexts of Chess is designed in consideration of the cultural role of chess as a combination of game, art, sport, and science using the interdisciplinary methods of the arts and humanities. This course will also explore practical resources available from local and national chess organizations, foundations, and associations for teachers introducing chess into their classrooms.

ED5345: Chess II - Institutional & Cultural Contexts of Chess (Graduate)

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The University of Maryland at Baltimore County is also one of the top universities for chess. This university offers a computer chess course as well as several continuing education courses. In the future, a three-credit honors course called Problem-Solving and Critical Thinking through Intellectual Sports will be offered for graduate students.

Different from other programs that schools want to incorporate, chess is very inexpensive. As a result, in this study, chess is recommended as a school activity. As with mathematics, chess is mentally demanding and requires patience to be successful. Working with developmental mathematics students in the past, they tend to lose patience when performing algorithms. When students lose patience in mathematics, they may give up completely. Chess players who lose patience at times understand that this is part of the game and will be more willing to continue playing. In the article, the author gives an introduction to the history and the game of chess that has been traced back thousands of years.

Chess and mathematics are also related in the fact that people feel that both are too difficult for the average person. The author states that the best school programs provide opportunities for students of all ability levels. Mathematics also has different ability levels as well.

Chess Improves Critical Thinking Skills

As many students are forced to take mathematics courses, chess players play chess voluntarily. Chess players are improving critical thinking skills while having fun at the same time. Developmental mathematics students feel prepared when they are required to use a lot of critical thinking. Unfortunately, these students are often “spoon-fed” the required information. As professors, we often don’t require students to “discover” an algorithm before using it. Students are not required to think about where the algorithm came from, they only need to know how to apply it. Some developmental math students don’t feel that they there is a need to critically think at this level of mathematics. Expectations of chess players to critically think appear to be much higher than those of the developmental math student. No matter what level you play chess, critical thinking is required. Developmental math students may not always be given opportunities to develop critical thinking skills.

Benefits of Chess

Although there have been no statistical methods or tests used, the New York City Schools Chess Program (founded in 1986 by Faneuil Adams Jr. and Bruce Pandolfini) has motivated young people in poor neighborhoods of the city. Many of the students I have worked with in developmental mathematics also come from poor neighborhoods. Maurice Ashley, the only African-American grandmaster in the world, also contributed to the program. This may convince

African-American students in developmental mathematics to disbelieve the stereotypes that African-Americans cannot achieve in chess.

Through academic and anecdotal records, Peterson(9) reports that Christine Palm (1990) writes about the existence of the NY Chess Program saying

- Chess instills in young players a sense of self-confidence and self-worth;
- 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 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, and finally;
- 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

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.

Chess Improves Intelligence

If chess instruction makes students smarter, it would seem logical to include chess in the schools' curriculums. Celone also agrees with this statement. He states, "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"(Celone). The next study, the author considers a student to be smarter if abstract reasoning and logical thinking skills are improved. In the study, a test (TONI-3) is given before and after 20 hours of chess instruction is given to elementary school children. "The TONI-3 is considered a valid and reliable instrument that has been highly associated with abstract reasoning and problem-solving (Celone, 2001, 1). The results of the study did show with significance that chess does improve the scores of the students on the TONI-3 test. It is known that these skills are also required for success in mathematics. As a result, Celone (2001) states in this article that another known author of chess research (Kennedy) thinks the chess should be included into the classroom for the following reasons:

- 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.

Conclusion

In reviewing the literature, one can see that chess can be very useful in enhancing the algorithmic computational skills needed in developmental mathematics. There have been only a few schools they have actually adopted the idea of using chess as a credit course in high school or community college. From my experience, students have difficulty in determining when to use certain algorithms. Chess would be an excellent game that can be used to improve these skills. Problem-solving is a major component in determining success in chess. Students in developmental mathematics have difficulty in these areas. Other areas of interest in chess are planning and critical-thinking. Planning in mathematics has many components ranging from completing a simple problem to planning how to prepare for a final exam. Chess players also plan by looking at a chess puzzle to determining what opening they may use in a national chess tournament. The major task in bringing chess into community colleges will be convincing the administration and students of these colleges that chess can definitely improve understanding in developmental mathematics courses as well as showing that there are many similarities between the algorithms used in developmental mathematics and those algorithms used in chess.

Completing an algorithm in both chess and mathematics requires critical thinking skills, strong basic foundations, continuous practice, error analysis, and a lot of patience. The rules of chess are given so that more people would take the time to learn how to play chess. Since a particular game of chess changes with every move, students are continuously using new algorithms learned from playing the game whereas students are simply given the algorithms in mathematics. Through students “discovering” the correct algorithms, students may get a better understanding of how and when to apply the steps of the algorithm Perhaps one day, teachers in mathematics would actually allow students to “discover” the algorithms to increase the understanding of the use of mathematical algorithms.

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