Does Chess Instruction Improve Algorithmic Computational Skills in Developmental Mathematics?

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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 perform algorithmic computations. Students are given formulas and are required to use the formulas to find solutions. Once students know the correct formula, they must apply the formula, then use steps taught in previous chapters to get the solutions. Students in developmental mathematics may know the formulas and the steps needed to get to the solution, but they do not know in which order the steps should be applied to get the solution. As students complete more practice problems, the problems appear to be changing. Some students do not realize that the same steps should be applied. Unfortunately, many students do not do enough practice problems to recognize that the problems they complete have similarities as opposed to thinking that different problems require different steps.

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 also very important in chess. Tournament chess players generally have a plan at the beginning of the game. This plan requires a player to have knowledge of a particular chess opening. As with mathematics, the plan requires careful studying. As students can analyze a test, players can analyze a chess game. Both use algorithms that students either used correctly or incorrectly. Students and players can get assistance as to the clarity of the algorithms used. These math tests and tournament games require “constant practice and study; memorizing; trying new ideas (more than one way to get an answer or solution) (Hall,5).

Chess players are not given formulas, but they can see how certain games are won by observing or reading about how the great chess players (grandmasters) are able to win their games. Given certain chess positions on a chessboard and the type of chess pieces on the board, an algorithm is used to win the game (checkmate) provided that the algorithm is applied in time (See figure 1). For example, if you have a queen, rook, and king, and your opponent only has a king, the position of the pieces is irrelevant. The steps used for a player to get the checkmate will remain the same. The challenge for chess players is the same as for those students in developmental mathematics. Both must ask, “To find the solution, what steps should I follow and how fast can I find it”?

Purpose of the Paper

The purpose of this paper is to explore whether chess instruction will improve the abilities of developmental mathematics students to perform algorithmic computations. This poses the question of incorporating chess instruction into the community college curriculum. Because I have had a large number of students fail my course as a result of not understanding what steps to use when required to complete math problems, I am particularly interested in incorporating chess instruction into the community college curriculum. I believe that 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”.

Rationale and References to Theory

If students have more experiences in using algorithms, they are likely to perform better in mathematics. Chess also improves patience and visual and spatial reasoning, which are other useful skills for developmental mathematics students. As a result of students missing these skills, the students are failing math courses at an alarming rate. For example, using the BCCC website (www.bccc.edu), one can verify that the Spring Semester of 2006 at Baltimore City Community College had 128 non-credit math courses out of 174 total math classes (73%) as a result of students taking these classes multiple times.

Obviously, it is a great advantage for both chess players and developmental mathematics students if students can understand the algorithms along with the order of steps involved with these algorithms. Since chess players use these algorithms so often, it is likely that chess players would have an edge intellectually in mathematics to those who do not play chess.

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

Community colleges would take an interest in this paper because of the poor performances of developmental mathematics students. Teaching chess at the community college level may improve performance in developmental 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 study can be used at any school from 8th grade and above that offers mathematics at any level since mathematics primarily uses algorithmic computations at these levels.

Literature Review

The Connection Between Chess and the Mathematical Content Standards

The first piece of literature I 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, he or she 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. 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.

"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.

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.

Implementing Chess as the University Math Requirement

Chess can be implemented not just at an elementary school level, but also on the college level. In this article (created as a story), Rolling Hills State University (a university name only implemented for this story) made an attempt to use a chess course to fulfill the university math requirement. The chess committee wanted to accomplish in a chess class what would resonate strongly with the NCTM Professional Standards for Teaching Mathematics (Schommer, 1991). The committee emphasized the following skills: (1) Critical Thinking/Problem Solving and (2) Collaborative Learning. Critical thinking is used often in chess since each move create a new problem. The author makes a good point in that the pre-fabricated exercises would limit critical thinking and give similar solutions which students may not be required to understand. For students to understand the algorithms used, collaborative learning can be an excellent way to achieve this task. Instead of students simply given the algorithms to use, students can be placed in small groups and attempt patterns as well as the proper algorithms required. In chess, players can work together to solve problems involving a variety of both simple and complex chess positions.

A Chess Proposal

It was the responsibility of the professors to come up with a proposal that would be approved by the University. Included in their proposal was the following:

- Traditional “lectures” occurred within the first week of the course. This included learning the basic moves and finding prevention methods of being checkmated. Also discussed would be suggestions to good play such as “play to the center of the board” and “control the middle squares.”
- Emphasis on the class would be on continuous play.
- Students do not have to memorize games or openings.

- Chess grandmasters would be invited to talk about their careers in Chess

The Difficulty of Grading a Chess Course.

After implementation of class, grading became a significant problem. Students were very critical of what the grades A,B,C,D, and F actually meant. Grades were actually computed by the students' abilities to beat a computer program at a particular level as well as playing each other and solving chess problems in groups. However, the work performed in groups was not always incorporated into the final grade. In fact, professors were unsure as to what portions of the course were most important. As with some developmental math students, some chess players got "A's" without doing any work outside of class. Professors felt that students were just aiming to find the solution which is one of the problems in developmental mathematics that the professors were trying to prevent. Professors were also unsure if beating a chess program was synonymous with improved critical thinking skills. As a result, they considered using a portfolio as a form of alternative assessment. This seemed to make grading even more difficult. Professors then did not know what could be included in the portfolio. When professors were accepting sculptures of chess pieces as part of the portfolio, other professors questioned how this idea of using a portfolio is appropriate for fulfilling a math requirement.

Possibilities for Future Chess Courses

Although the chess course was not as the professors would have liked it, students were generally happy with what they have learned from the class. The idea could still be used if grading was clear and consistent amongst professors and students. So the committee was undecided about offering the course for the next semester.

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

Effects of Chess Instruction on Mathematical Achievement

The next study by Smith(1998) was one of the few primary research studies that I reviewed. This student looks at the effects on chess instruction on the mathematics achievement of southern, rural, black, secondary students. Treatment group received 18 weeks of chess instruction. There were 8 males and 11 females in the treatment group. ANOVA tests used found no significant difference in mathematics achievement between the treatment and the control group. In this primary research study, an acknowledgments section was included. Many of the other research studies that I have reviewed in the past does not include an acknowledgement section..

Field Dependence and Field Independence

The next study focused primarily on the definition of field independence and field dependence. "It is therefore no surprise that the individual with the best mathematics achievement (developmental mathematics students) also demonstrates the greatest degree of field independence” (Smith, 1997, 1). Field independent individuals are more focused on remembering and noticing details. They are very good at critical and logical thinking. It will be these individuals who will use their critical thinking and logical thinking skills to perform algorithms effectively. Schmeck(2) describes these people by stating that they have an interest in operations and procedures, or the “proper” ways of doing things and prefer step-by-step, sequential organizational schemes. They are not influenced by others and are not as easily frustrated. Field dependent individuals are described as looking at problems from a global approach. They are more interested in group work and occupations that are people-centered. They tend to primarily look at the big picture while being interested only in the solutions and not the details behind the solutions. Research shows that Field Dependence is highest amongst minorities and females (Smith, 5). Ironically, African-Americans students tend to be placed in developmental math courses as opposed to being placed in credit math courses. It is very important for developmental mathematics students to be aware of the details in various problems or they will have trouble determining what algorithms should be used for a given problem. For example, a chess player cannot use an algorithm (sequence of moves) until the pieces are in their proper places. Similarly, a developmental math student cannot use the algorithm of the quadratic formula until the equation is algebraically manipulated to $ax^2 + bx + c = 0$.

There appears to be an achievement gap between field dependent and field independent individuals. Many have already done research on this achievement gap. It would be interesting to know if the achievement gap between whites and minorities is similar to the achievement gap between developmental math students and non-developmental math students.

Project Independence

Other countries such as Venezuela also had this achievement gap and began a program called Project Independence. The purpose of this project was to improve the thinking abilities of high school students. One of the interventions was the introduction of chess into the schools. Chess was selected because “playing chess enhances certain intellectual abilities related to abstract thinking, problem solving, and analysis of spatial relationships (Smith, 1998, 7). The project involved 230 children aged 7-9 from various backgrounds. The investigators of the project did conclude that there was an improvement in achievement, but the project was cut due to funding.

Transfer of Chess Skills to Other Domains

Also included in this study is a theoretical model which assumes that skills acquired in one domain can be transferred in other domains. This is very important for other researchers who may want to use this study. One of the major strengths of this study is that it could be used in other schools and students of all ages can be participants of this type of study. To transfer the study, chess instruction should emphasize visualization, critical thinking and problem solving (Smith, 1998). Another condition is the use of algorithmic computations and when to apply the algorithm. It would be the responsibility of the teacher to strengthen the link between chess and mathematics. Depending on the type of instruction, it may result in bias of the study.

Limitations of the Study

Some of the limitations in this study were as follows: (1) all subjects were African-American (2) subjects were all between 16-17 (3) all subjects were taught by the researcher (4) there were a small number of subjects and (5) treatment and control groups were not controlled in their choices of mathematics courses. Overall, despite the limitations, I think that this was a good study. Making some adjustments to the limitations listed would be likely to give more details about the relationships between chess and mathematics. Since this study can transfer into other domains, researchers should have opportunities to fix these limitations if they choose to do so.

Hypothesis of the Study

The hypothesis that were investigated in the study were (1) Chess instruction will have no effect on the mathematics achievement of the treatment group (2) Chess instruction will have no effect on the degree of field independence/dependence of the treatment group and (3) chess instruction will have no effect on the spatial ability of the treatment group. Having three different hypotheses was also strengths of the study. Researchers in the fields of both mathematics and psychology may find some use in this study.

Effect of Chess Instruction on Field Dependence and Field Independence

The next study was very similar to the previous study. The purpose of this study was to determine if chess instruction would change the measure of a student's field dependence/independence in the direction of stronger field independence. Field independent individuals are more analytical, an advantage in the field of mathematics. They are also known for solving problems rapidly (Smith, 1997) which is very useful in performing algorithmic computations.

In this study, which began on January 29th, 1997, 11 high-school humanities students received 50 hours of chess instruction received afterwards the Group Embedded Figures Test (GEFT). The students (4 males and 7 females) were given a pre-test and a post-test after instruction was given.

Chess instruction enabled students to perform more Field Independent behaviors which is likely to improve students' abilities to perform algorithmic computations. The chess instruction in this study was given by a teacher certified to teach Physics, Chemistry, Biology, General Science, Physical Science, and Mathematics by the state of Louisiana. The instructor holds a United States Chess Federation (USCF) Rating of 1635 (I have a USCF rating of 1623).

Null Hypothesis of Study

The null hypothesis was that there was no significant difference between the mean score of the GEFT administered before chess instruction compared to the mean score after receiving chess instruction. Comparing the calculated t-value of 2.8 to the t-value at the .05 level of 2.238, the null hypothesis was rejected. Therefore, chess instruction did have a significant difference in the GEFT scores.

Conclusion of Study

In conclusion of this study, it was shown that chess had a significant effect on scores of the GEFT, but it could not guarantee that chess would have a significant effect on mathematics achievement in general. Since research shows that a high score on the GEFT is synonymous with a high score on mathematics achievement tests, it is likely from previous studies that chess would increase mathematics achievement.

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)

Chess as a Club or School Activity

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.

Although chess courses are in the curriculum in only a few schools, there are many schools around the country that have chess clubs. The next study I reviewed looked at determining if the participation in a chess club would improve standardized test scores. The subjects were third and fifth graders at Klein Independent School District in Spring, Texas. There was significant evidence ($p < .00001$) that regular track chess players score higher on the standardized test (Texas Assessment of Academic Skills -- TAAS) than non-chess players.

An interesting part of this study was the requirements of the chess club and its members. In order for chess to be used in the schools, organization of the club is critical. In this district, there were four elementary schools surveyed. The chess clubs at these elementary schools surveyed. The chess clubs at these elementary schools were coordinated differently. In one school, a faculty member teaches chess to club members. At another school, the parents of students of the district taught chess to the club members. In all the elementary schools, the clubs met one hour a week after school one day a week and the schools did not play a role in funding any of the school activities. The chess club used fundraisers to raise money for chess equipment and participation in tournaments.

Unfortunately, like mathematics, several faculty members are intimidated by teaching chess. To prevent this intimidation of faculty members, teachers would need to be trained through a rigorous chess training program. Liptrap (1998) supports this statement by stating that "some in-service training of elementary teaching staff would be necessary, as few teachers have much background about chess, and most have great fear of chess". It will be difficult to bring chess into the schools without faculty support.

The article does not define what is meant by "participation". If a student attends once or twice, but never returns to the club, would that student be a part of the study? If a club member has poor attendance (only attends half of the meetings), is this member still a part of the study? Also, what if a student is in attendance, but does not participate in any of the activities? I think that these questions should be addressed in the article. This may have some impact on the results of the study. It appears that the assumption should be made that all chess club members have good attendance and participate in the activities for the day.

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.

Precision of Chess and Mathematics

“The major aesthetic appeal of chess is the efficiency, the precision, the power, and the originality of the tactics and strategy of the game itself”(Hall, 2003,3). Precision is also critical in mathematics. Students have to be precise when performing each step in an algorithm. One small error in one step leads to errors in all steps afterwards. Precision also applies to writing down steps carefully so that one can see how one step applies from the previous step. It is also true in chess that one bad move leads to fatal consequences.

Benefits of Chess

The author Hall (2003) provides many examples as to why chess should be played as a hobby and all of its benefits. He also states in the article that those who play chess more find chess most rewarding. These chess players who play more are also more successful. Of course, this is true in mathematics in that students who practice more tend to perform better in mathematics. “Proficiency in chess seems to be related to inherent logic, problem solving ability, temperament, competitiveness, appreciation, and versatility in thinking for the beauty of the game” (Hall, 2003, 5). These characteristics also appear to be true for mathematicians. As one who has completed several high-level mathematics courses, these characteristics were very important in my success.

Support of Chess

The last subheading of this article tells others how you could support chess. This section is very important because administrators must support chess to implement chess into the curriculum. Other faculty members will also have to be convinced in order to support chess. Again, it would be very inexpensive to provide training to teachers and buying proper materials. As decision-making is so important in chess, decision-making is the deciding factor in bringing a game with international appeal into our schools.

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.

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

Peterson's summary of chess education is very helpful in viewing chess from a

variety of perspectives. The studies took place all over the world and were used for students of all ages. Regardless of the age of the students, these students (through the chess instruction) received a lot of experience using memory. In order for developmental mathematics students to use algorithms on tests, they must remember the algorithms. Peterson's summary has demonstrated the importance of using chess to improve memory. Grandmasters are able to memorize certain chess positions on the chessboard. The grandmasters can then apply a known algorithm to get the desired result.

Chess Improves Intelligence

If chess instruction makes students smarter, it would seem logical to include chess in the schools' curriculums. 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.

The Search for Research

I had a very hard time finding empirical research on this topic. I did find research articles on chess and mathematics, but not the two topics together. When searching the topics individually, the amount of material is overwhelming.

The chess material primarily discusses chess history as well as other forms of chess. I would not get any information on chess if I don't use the word "chess" as part of my search. If I do not include the word "education" as a part of my search, I often got only examples of puzzles relating chess to mathematics. To maximize the amount of material I would get, I did a cross search through the following databases and received the following hits: Academic Search Premier(6), Article First (0), Books in Print (0), Digital Dissertations (5), Education Journals (3), ERIC (EBSCO) (22), ERIC (FirstSearch) (28), Research Library (4), Teacher Reference Center (3), WilsonSelect Plus (0), World Almanac (3) and WorldCat (9). I reviewed every hit to determine if it was relevant to my topic. Only a few of these were actual empirical research. The other hits were mainly articles. Some journals (for particular years) that Morgan State's Library did not have were Arithmetic Teacher, Australian Math Teacher, and Mathematics Teacher. In general, in all searches, I had to use "chess" and "mathematics" and "education" in order to get material relevant to my topic. I also looked at the majority of the databases that would likely include mathematics and chess as articles. Searching the Internet, I was really not able to find research. Most of the material from the Internet was opinion papers. However, the Internet can be used to find the authors of empirical research articles. I looked at the United States Chess Federation Website for research, but it was primarily related to chess only. So I would have to conclude from my research that there is a lot that can be added to these topics.

Figure 1

Analyze the following chess position (Rook-King-Queen vs. King checkmate)

Chess Algorithm (Assume that you are playing White and the black King is on the nth rank)

Algorithm 1: Black King is on first through fourth rank

Goal: Checkmate King on first rank

If the White King is in the rectangle formed between the position of the Black King and the piece(other than the White King) furthest from the King, move the King completely outside of this rectangle. After the King has moved outside the rectangle, continue the given algorithm and the new (or same) position of the King should be the nth rank.

Move 1a: Move Rook or Queen (whichever is furthest from the King) to the (n+1)st rank on a square non-adjacent to the King.

If the Rook or Queen is already on the (n+1)st rank,

Move 1b: Move *the other piece* (the piece not on the (n+1)st rank) to "check" the King provided that *the other piece* would not be on a square adjacent to the King.

If the "check" results in *the other piece* being adjacent to the King or if there is another piece on the file so that the "check" cannot happen,

Move 1c: Move *the other piece* to the file furthest from the King so that it is the only piece on that file.)

Move 2: Move *the other piece* to the nth rank.

Move 3: Move piece on (n+1)st rank to (n-1)st rank provided that the piece will not be adjacent to the King. If the piece would end up being adjacent to the King, move the piece to the file furthest from the King so that it is the only piece on that file.

Move 4: Move piece on nth rank to (n-2)nd rank provided that the piece will not be adjacent to the King. If the piece would end up being adjacent to the King, move the piece to the file furthest from the King so that it is the only piece on that file.

Move 5: Move piece on (n-1)st rank to (n-3)rd rank provided that the piece will not be adjacent to the King. If the piece would end up being adjacent to the King, move the piece to the file furthest from the King so that it is the only piece on that file.

Move 6: Move piece on (n-2)nd rank to (n-4)th rank provided that the piece will not be adjacent to the King. If the piece would end up being adjacent to the King, move the piece to the file furthest from the King so that it is the only piece on that file.

Move 7: Move piece on (n-3)rd rank to (n-5)th rank provided that the piece will not be adjacent to the King. If the piece would end up being adjacent to the King, move the piece to the file furthest from the King so that it is the only piece on that file.

A solution (checkmate) should be found after the algorithm is complete.

Mathematical Algorithm

Consider the following equation:

$$\frac{2(x - 7)}{6} + \frac{4x + 7 - 3x}{2(x + 1) - 3x + x} = \frac{7(x - 4)}{12}$$

Use the following algorithm to solve linear equations:

Step 1: Simplify denominators

Step 2: Simplify numerators (maintain parenthesis)

Step 3: Multiply all terms by the LCD

Step 4: Use distributive property.

Step 5: Combine like terms.

Step 6: Use addition or subtraction to move variables to one side of the equation and numbers to the other side of the equation.

Step 7: Use multiplication or division to solve for the variable.

Step 8: Check answer by substituting into the original equation.

The similarities between the two algorithms are as follows.

I. Depending on the complexity or simplicity of the equation or the chess position, all steps of the algorithm are not required, but the steps should be done in order.

a) For example, solving the equation $2x + 6 = 12$ only requires steps 6, 7, and 8, but in that order. Step 7 cannot be done before step 6.

b) In the chess position below, only one move would be required to win the game. We would not need to do the other steps in the algorithm.

II. The steps in the algorithm must be clearly understood.

a) Common errors that may be made in trying to find the solution of the equation above would be (1) Incorrect use of the distributive property (2) not combining like terms or combining terms that that are not like terms (3) Not being able to find LCD (4) Not multiplying all terms by the LCD correctly (5) Incorrect use of the addition property (adding on one side but subtracting on the other side) (6) Careless mistakes in adding, subtracting, multiplying, or dividing signed integers (7) Not taking the time to check the equation.

b) In the chess position above, since black has only its King, white must win the game in 50 moves or the game is considered to be a draw (tie), common errors which would make it hard for white to win would be (1) placing a piece adjacent to the King that is not protected (if one of the pieces are captured, a solution (checkmate) can still be found but it is much harder, similar to using a common denominator instead of the least common denominator, but if both the Rook and Queen are captured, a checkmate cannot occur) (2) Not moving a piece that is being attacked by the black King (3) Moving a piece away from the King, but placing the piece on the same file as another piece (this error may increase the number of steps in the algorithm)

III. In both the equation and the chess position, an error made in the algorithm does not necessarily mean that a solution(checkmate) cannot be found.

a) In the chess position, poor moves may be made by White (allowing the King to stay in the middle of the chessboard), but a solution can be found after a while if the algorithm is followed. Also, the opponent can make poor moves making the steps in the algorithm easier to follow (the rule of thumb in chess is that you always assume that your opponent makes the best moves).

b) In the equation, if an error is made by moving both the variables and the numbers to the same side of the equation, a solution can still be found by moving either the variables or numbers back to the other side of the equation. It may also occur that two careless errors will occur in the same problem that may offset each other.

IV. Although not addressed in this paper, one may find shortcuts with a lot of practice.

a) The King may be used as a protecting piece for either the Queen or Rook. It would depend how close the white King is to the black King. The Rook and Queen can also protect each other so that a solution(checkmate) can be found much faster.

b) After completing steps in the algorithm, the equation would look like the linear equation ax + b = c. Solving this equation for x gives –b/a. This can be seen without any steps if the equation is written in this form. When students complete more problems, they start to look very similar to each other.

V. Small adjustments can be made to the algorithms listed above.

a) If the King is on 5^{th} through 8^{th} ranks, the algorithm can be adjusted accordingly. Also if the King is on the 1^{st} through 4^{th} file or if the King is on the 5^{th} through 8^{th} file, we can make small adjustments to the algorithm. The reason that the adjustments would be minimal is because of the symmetry of the chessboard.

b) In solving these equations, the steps change slightly depending on the textbook. Some textbooks might combine some of these steps together.

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. I would challenge beginners of chess to try to create new algorithms by randomly placing the Black King and the White King, Rook, and Queen at different places on the chessboard. Perhaps one day, teachers in mathematics would actually allow students to “discover” the algorithms to increase the understanding of the use of the algorithm.

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