Chess Instruction in the Mathematics Classroom:

Implications for Critical-Thinking and Academic Skills:

A Meta-Synthesis

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Abstract

Chess instruction during the school day or in a club format has been shown to increase achievement in mathematics, science, and reading comprehension. Students of all achievement levels experience positive growth in achievement within a relatively short period of time. Critical thinking skills, perseverance, and motivation to learn are also increased with the implementation of chess instruction. This meta-analysis of the literature on chess instruction and critical thinking skills investigates the increasing mathematics, science, and reading comprehension for students, particularly those who experience learning disabilities.

1. Introduction

1.1 Background

One of the important goals in education is to teach children to think critically (Jones, 1990). Children must be taught to make reasoned choices and decisions based on evidence before them in an ever-changing environment. Chess is an excellent way to teach children to think in these ways. Chess players are constantly making decisions about whether to attack or defend and how to best place pieces to gain an advantage.

Chess has been a part of many school curricula around the world for many years. In fact, Armenia is the first country in the world that mandated chess in the classroom, in 2011. Second through fourth graders must receive two hours of chess instruction per week. This project was not only designed to increase Armenia's chess talent, but also to foster creative thinking. While still in its introductory phase, children are showing signs of enjoying this addition to their education as well as seeing the beginning of increases in academic performance (Hakobyan, 2013).

There is a dearth of scholarly articles that directly link chess to an increase in specific academic performance. For example, chess cannot be found to increase specific skills in geometry. However, there are a number of studies that have found that strategy games, and specifically chess, contributed to increased achievement in mathematics and critical-thinking skills in third through sixth graders (Ferreira & Palhares, 2008). Ferreira and Palhares found a relationship between chess play and children's ability in finding patterns in critical-thinking. These same skills were used in chess. Rifner and Feldhusen (2007) also found that chess helped students foster logical-thinking and critical-thinking skills.

Learning disabilities are categorized as high-incidence disabilities. These are further

defined by the Individuals with Disabilities Education Act of 2004 (IDEA), using specific criteria. IDEA defines a disorder as the imperfect ability to think, listen, process, spell, write, and/or complete mathematical calculations. These are as a result of developmental aphasia, brain injury, brain dysfunction, and perceptual ability (34 Code of Federal Regulation §300.7(c)(10)). Students with a learning disability experience performance that is substantially below that which is expected of them at a particular grade level and assessed intelligence. The significance of the discrepancy between performance and ability must affect learning to an extent that specific accommodations and interventions are necessary for academic success (American Psychiatric Association, 2013).

Smith and Luckasson (1992) noted that students with disabilities often lack critical thinking and thinking skills. There needs to be direct instruction in how to solve problems and how to look at a problem critically. This can be done through the medium of critical-thinking games or role-playing. Chess is a critical thinking game that can, not only teach critical thinking skills and critical-thinking, but it can also be used as a metaphor for a number of different learning concepts. Students can learn the genetic hierarchy of the animal kingdom from looking at the different pieces on the board. They can learn strategies used in historical events. These metaphors must be explicitly taught in order to make the transference from the board to the concept (Smith & Luckasson).

Chess can be a vehicle for not only teaching critical thinking skills and problem solving, but also a vehicle to motivate students to learn. If a student can be engaged in learning a game as a means of entering into a learning situation, then students may find the motivation to continue to learn in a more formal learning environment. This may alleviate, not only some of the learning difficulties that students who experience a learning disability experience, but also alleviate some feelings of

frustration about learning and repeated failure.

1.2 Author's beliefs and experiences

I began to play chess as a child, when my father taught me the game. He never believed in letting me win chess, but rather wanted me to learn the game and its intricacies as well as I could. It was many years into my chess career that I first beat him. We played often, and my frustration in losing to him only fueled my motivation to learn the game well enough to beat him.

Another reason I chose to continue to pursue the game of chess, was the endless opportunities that it gave me to learn about the game. Chess is a complex game with an almost infinite number of moves. After the first move, by both players there are 400 possible moves. After the third move by each player, there are more than 9 million possible positions. This allows for many different ways to win the game and many different forms of play.

As I became an adult, I learned more intricate ways to play the game and became a rated chess player with the United States Chess Federation. I joined clubs wherever I lived, and participated in chess tournaments to improve my play. When I moved to Anchorage, where the pool of chess players is small, I became the chess tournament director for the local chess club and promoted both adult and scholastic play in Anchorage. It was at this time that I began to investigate the usefulness of chess as a vehicle to teach critical thinking skills and to increase academic performance for students. I ran chess clubs in various schools my children attended and then as a staff member in the Anchorage School District.

As I taught scholastic chess, I became aware of the varying aptitudes for chess. I also became acutely aware that some children lacked the ability or the skills to think through the game of chess. It was not that they did not understand the game. They simply could not process

the different options available for every move. It was then that I began to see what I could do to help these students to work on the skills they needed to become better chess players. We worked on various critical-thinking skills such as drawing a picture of all the possible moves. Tracing the moves with a finger, on the board. I also gave students pictures to follow, for the movement of each piece. As students were able to access different tools to help them remember the processes, they became more equipped to play chess and more confident in their ability to do so.

Some of the time, as students were learning the skills to learn the game of chess, they became discouraged and unmotivated. They had to persevere through the tough challenges presented to them. This was difficult for many students and they struggled with what they perceived as failure. It was then that I learned that I needed to reframe failure for them. I worked with students to teach them that making a wrong move / mistake is not failure. Failure is when you make a wrong move or mistake and don't learn from it. Perseverance is what ensures success.

All of these aspects of learning the game of chess are what makes me so passionate about the game and the possibility of using it as a vehicle to teach students critical thinking skills as well as the art of chess. My hope is to be able to show the research support for this as an educational opportunity, not just for high-achieving students, but also for students who experience a learning disability.

With this meta-analysis, I hope to investigate the following research questions: 1. Does teaching chess in mathematics class, result in a measurable increase in students' mathematics achievement?

2. Does teaching chess in mathematics class, result in a measurable increase in students' critical-thinking skills?

3. Does teaching chess to students who experience learning disabilities increase their critical-thinking skills and thus, their mathematics achievement?

1.3 The purpose of the meta-synthesis

This meta-analysis, which focused on the usefulness of chess instruction in the mathematics classroom on academic and critical-thinking skills achievement, for students who experience learning disabilities, had multiple purposes. One purpose was to review the research literature on chess instruction in mathematics class, with specific focus on increasing critical thinking skills. A second purpose was to review the research literature on chess instruction in mathematics class, with specific focus on increasing mathematics academic skills. A third purpose was to review the literature for usefulness of chess instruction for students who experience learning disabilities.

Students in special education mathematics classes seem to have difficulty honing in on the important information in a problem. They often are distracted by the non-essential information, or the barely-relevant information. I believe that chess is a game that is uniquely adept at challenging students to look at all the information presented by an opponents move, and hone in on the important and relevant information to choose the next correct move. This skill will, hopefully, transfer into the mathematics context, by allowing students to hone in on the important information in the text of a problem, and determine what the next correct move is, based on the most important information.

In addition, chess has so many variables that I believe that playing it helps teaching flexibility in thinking. This flexibility is a skill that students need in finding multiple paths to a correct answer, or looking for all possible answers to a problem. In chess, not all possible answers may lead to checkmate, but there are often many pathways that will increase dominance on the

board, and work to the player's advantage. The ability to seek out these multiple pathways is crucial to powerful thinking in the mathematics classroom.

2. Methods

2.1 Selection Criteria

The 36 journal articles and 1 book included in this meta-synthesis met several criteria. They are:

1. The articles dealt with issues related to chess and teaching students critical-thinking skills. 2. The articles dealt with issues related to chess and increasing students' mathematics academic skills.

3. These articles dealt with using chess and a medium for teaching students in special education, critical-thinking, and mathematics academic skills.

4. These articles explored the relationship between strategy games such as chess, and their usefulness in teaching critical-thinking skills.

5. These articles dealt with issues associated with making the connection between chess and critical-thinking strategies in other content areas.

6. These articles dealt with using chess to help increase mathematics achievement in students who receive special education services.

7. These articles were published in peer-review journals in the fields of psychology, problem based learning, mathematics education, gifted education, and child psychology. 8. A small number of articles were research papers located online at universities such as the University of Texas, Dallas.

9. Articles were published between 1974 and 2013.

2.2 Search Procedures

Database searches were conducted in EbscoHost, Education Resources Information

Center (ERIC), and Google Scholar to locate articles for this meta-synthesis. *2.2.1 Database Searches*

I conducted Boolean searches within the EbscoHost, ERIC, and Google Scholar databases using the following search terms:

1. (“chess”) AND (“critical thinking”).
2. (“strategy games”) AND (“critical thinking”).
3. (“Chess”) AND (“special education”).

These database searches yielded a total of 15 articles (Adams, 2012; Barrett & Fish, 2011; Batchelder & Alexander, 2012; Bogard, Liu, & Chiang, 2013; de Groot, 1978; Ferguson, 1995; Frank, 1978; Gaudreau, 1992; Gliga & Flesner, 2013; Liptrap, 1993; Nurse, 1995; Rifner & Feldhusen, 1997; Smith & Cage, 1998; Storey, 2000; Thomas-EL, 2012). *2.2.2 Ancestral Searches*

An ancestral search involves reviewing the reference lists of previously published works to locate literature relevant to one’s topic of interest (Welch, Brownell, & Sheridan, 1999). I conducted ancestral searches using the reference lists of the previously retrieved articles. These ancestral searches conducted on the citations of articles located in my database searches, yielded 10 additional articles that met the selection criteria (Bankauskas, 2009; Bulgren, J. A., Deshler, D. D., & Lenz, B. K., 2007; Horgan, 1987; Leshowitz, et al. 1993; Mastropieri, M. A., Scruggs, T. E., Norland, J.J., Berkley, S., McDuffie, K., Tornquist, E.H., et al., 2006; Moran & Jarvis, 2001; Perkins & Salomon, 1989; Robitaille, 1974; Root, A. W., 2008; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk, et al., 2008).

2.3. Coding procedures

I used a coding form to categorize the information presented in each of the 25 articles.

This coding form was based on: (a) publication type; (b) research design; (c) participants; (d) data sources; and (e) findings of the studies.

2.3.1. Publication types

Each journal article was evaluated and classified according to publication type (e.g., research study, theoretical work, descriptive work, opinion piece/position paper, guide, annotated bibliography, review of the literature). *Research studies* use a formal research design to gather and/or analyze quantitative and/or qualitative data. *Theoretical works* use existing literature to analyze, expand, or further define a specific philosophical and/or theoretical assumption. *Descriptive works* describe phenomena and experiences, but do not disclose particular methods for attaining data. *Opinion pieces/position papers* explain, justify, or recommend a particular course of action based on the author's opinions and/or beliefs. *Guides* give instructions or advice explaining how practitioners might implement a particular agenda. An *annotated bibliography* is a list of cited works on a particular topic, followed by a descriptive paragraph describing, evaluating, or critiquing the source. *Reviews of the literature* critically analyze the published literature on a topic through summary, classification, and comparison.

2.3.2. Research design

Each empirical study was further classified by research design (i.e., quantitative, qualitative, mixed methods research). *Quantitative* research utilizes numbers to convey information. Instead of numbers, *qualitative* research uses language to explore issues and phenomena. *Mixed methods* research involves the use of both quantitative and qualitative methods to present information within a single study.

2.3.3. Participants, data sources, and findings

I identified the participants in each study (e.g., students, students with learning disabilities, students in school, students out of school, elementary-aged students, middle school aged students). I also identified the data sources used in each study (e.g., observations, surveys, achievement tests, problem-solving instruments, standardized tests). Lastly, I summarized the findings of each study (Table 2).

2.4. Data analysis

I used a modified version of the Stevick-Colaizzi-Keen method previously employed by Duke (2011) and Duke and Ward (2009) to analyze the 25 articles included in this meta synthesis.

3. Results

3.1 Publication type

Table 1

Author(s) & Year of Publication	Publication Type
Adams, 2012	Research Synthesis
Bankauskas, 2009	Research Synthesis
Barrett & Fish, 2011	Research Study
Batchelder & Alexander, 2012	Research Study
Bogard, Liu, & Chiang, 2013	Research Study
Bulgren, et al., 2007	Research Synthesis
deGroot, 1976	Research Study
Ferguson, 1995	Conference Proceeding
Frank, 1978	Research Study
Gaudreau, 1992	Research Study

Gliga & Flesner, 2013	Research Study
Horgan, 1987	Research Study
Leshowitz, et al., 1993	Research Study
Liptrap, 1993	Research Study
Mastropieri, Scruggs, et al., 2006	Research Study
Moran, 2001	Research Study
Perkins & Salomon, 1989	Research Study
Rifner & Feldhusen, 1997	Research Study
Robitaille, 1974	Research Study
Root, 2008	Research Study
Scholz, Niesch, et al., 2000	Research Study
Smith & Cage, 1998	Research Study

Storey, 2000	Research Study
Thomas-EL, 2012	Research Study
Nurse, 1995	Research Study

3.2 Research design, participants, data sources and findings of the studies As stated previously, I located 16 research studies that met my selection criteria (Barrett & Fish, 2011; Batchelder & Alexander, 2012; Bogard, Liu, & Chiang, 2013; Bulgren, J. A., Deshler, D. D., & Lenz, B. K., 2007; de Groot, 1978; Frank, 1978; Gaudreau, 1992; Gliga & Flesner, 2013; Horgan, 1987; Leshowitz, et al. 1993; Liptrap, 1998; Mastropieri, M. A., Scruggs, T. E., Norland, J.J., Berkley, S., McDuffie, K., Tornquist, E.H., et al., 2006; Moran & Jarvi, 2001; Nurse, 1995; Rifner &

Feldhusen, 1997; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk, et al., 2008; Smith & Cage, 1998). The research design, participants, data sources, and findings of these studies are identified in Table 2.

Table 2

Authors	Research Design	Participants	Data Sources	Findings
Barrett & Fish, 2011	Quantitative	6^{th}-8^{th} grade students in special education mathematics classes in Texas	Texas Assessment of Knowledge and Skills (TAKS), course grades.	Increase (over control group) in overall mathematics course grade, overall TAKS scores, specific score increase in: Numbers, Operations, and Quantitative Reasoning and Probability and Statistics.
Batchelder & Alexander, 2012	Qualitative	Graduate students in a problem solving theory class.	Observations from graduate students	Insight problem-solving is one of the highest forms of problem-solving. It is difficult to test for. Chess was found to be one of the games that can be successfully used to test for this level of problem-solving. These findings indicate that chess is indeed a higher-order thinking game that promotes complex problem-solving skills.
Bogard, Liu, & Chiang, 2013	Quantitative	Graduate students	Clinical problem solving trials	Students need supports at different levels of the problem-solving process in order to progress to higher levels of problem-solving.

deGroot, 1976	Quantitative	Chess masters	Theoretical Analysis	Chess masters can perform at high levels due to the ability to chunk information and retain it in long-term memory. This results in a bank of knowledge to draw upon.

Frank, 1978	Quantitative	High school in Kisangane, Zaire	General Aptitude Test Battery, Primary Mental Abilities Test, Differential Aptitude Test, Rorschach	Students were split into an experimental and control group. Experimental group replaced two hours of mathematics instruction with chess instruction, per week. Experimental students scored significantly higher in arithmetical aptitude and verbal logic after a year of intervention.
Gaudreau, 1992	Quantitative	437 fifth graders	Achievement tests	Three groups were formed. Group A received traditional mathematics class. Group B received enriched mathematics class with chess and problem-solving instruction. Group C received enriched mathematics instruction with chess and problem-solving instruction, starting at the first grade. Groups B and C scored higher in problem-solving and comprehension. Group C's gains were the highest.

Horgan, 1987	Quantitative	24 elementary students, grade 1-6; 35 junior high and high school students.		Children can perform highly complex tasks as well as adults. Children learn from global to detail, while adults learn expertise by giving attention to detail. This is a more efficient route to expertise than adults use.
Leshowitz, et al., 1993	Quantitative	22, 7-12 grade special education students, control group of 33, 11th grade general education students.	Pre- and post-test data, critical thinking and mathematics achievement tests.	Students in experimental group scored equal to or higher than the control group. This indicates that is students with learning disabilities receive interventions to teach critical thinking skills, they have the ability to perform at the same level as their typical peers.
Liptrap, 1998	Quantitative	3rd through 5th grade students in four schools	Texas Assessment of Academic Skills	Chess players in third grade did not score significantly higher than non-chess players, but by fifth grade they scored significantly higher in reading and mathematics. Special education students made fewer gains, but were statistically significantly higher than their non-chess playing pairs. Results for gifted students were not clear due to test ceiling issues.

Gliga, & Flesner, 2013	Quantitative	30 primary grade, Romanian students	Dearborn Test of IQ, School Performance Test of Mathematics and Romanian Language	Students in the experimental group showed statistically significant increases in mathematics and Romanian language achievement, over the control group after a 10-week chess intervention.
Mastropieri, Scruggs, et al., 2006	Quantitative	13 eighth grade science classes, randomly assigned to experimental and control.	State Achievement Tests	Peer-mediated, differentiated learning in an inclusive classroom increases achievement for all students.
Moran, & Jarvis, 2001	Action Research	Preschool class	Observations	Teacher-driven explorations that require students to look back at previous work and improve or edit, results in more thoughtful responses from young children.
Wang Fung, as cited in Nurse, 1995	Quantitative	University students	Mathematics and science achievement tests	Mathematics and science achievement rose 15% after learning how to play chess, and playing regularly.

Rifner & Feldhusen, 1997	Mixed Methods	Middle school students – gifted and average students	National Chess Rankings, problem solving task	Gifted and average students in and not in the chess program were given a problem-solving task pre- and post the intervention. They had to a Shakespearean sonnet. Gifted students in the chess program outperformed both their intellectual peers as well as the average students in the problem-solving task. All students in the chess program, who attended raised their chess rankings between 60 and 100 points over a year. Gifted students made greater gains than their average peers.
Scholz, Niesch, et al., 2000	Quantitative	German special education students	Pre-test and post-test in concentration and calculation	Students who received chess instruction in place of one mathematics lesson improved over control group in simple addition and counting. Concentration and calculation abilities were no different.
Smith & Cage, 1998	Quantitative	21 female and 20 male, African American, rural high school students.	Pre-test and post-test in mathematics achievement and non verbal ability.	Students who participated in a 120-hour chess program showed significant increases in mathematics achievement and non-verbal cognitive ability.

3.2.1 Research Design

Fourteen of the 16 studies (81.25%) use a quantitative research design (Barrett & Fish, 2011; Bogard, Liu, & Chiang, 2013; Bulgren, J. A., Deshler, D. D., & Lenz, B. K., 2007; de Groot, 1978; Frank, 1978; Gaudreau, 1992; Gliga & Flesner, 2013; Horgan, 1987; Leshowitz, et al. 1993; Liptrap, 1998; Mastropieri, M. A., Scruggs, T. E., Norland, J.J., Berkley, S., McDuffie, K., Tornquist, E.H., et al., 2006; Nurse, 1995; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk, etal., 2008; Smith & Cage, 1998). One of the studies (6.25%) utilized a qualitative research design (Batchelder & Alexander, 2012). One of the studies (6.25%) utilized a mixed method research design (Rifner & Feldhusen, 1997). One of the studies (6.25%) used an action research design (Moran & Jarvis, 2001).

3.2.2 Participants and data sources

The majority of the 16 research studies included in this meta-synthesis analyzed data from school-aged students from special education, general education, and gifted education classes. Four of the studies, (25%) analyzed data collected from elementary-aged students (Gaudreau, 1992; Horgan, 1987; Liptrap, 1998; Gliga & Flesner, 2013). Three of the studies, (18.75%) analyzed data collected from middle school-aged students (Barrett & Fish, 2011; Mastropieri, M. A., Scruggs, T. E., Norland, J.J., Berkley, S., McDuffie, K., Tornquist, E.H., et al., 2006; Rifner & Feldhusen, 1997). Four of the studies, (25%) analyzed data collected from high school-aged students (Frank, 1978; Leshowitz, et al. 1993; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk, et al., 2008; Smith & Cage, 1998). Two studies (12.5%) included special education students, one from middle school and one from high school (Leshowitz, et al. 1993; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk, et al., 2008). One study (6.25%) included students who were identified as gifted (Rifner & Feldhusen, 1997). In addition, to school-aged students, data were also analyzed from other participants. These additional participants included

preschool, undergraduate, and graduate students as well as one group of chess masters. Achievement scores in mathematics, reading, and problem-solving provided the main data sources in the research studies. Ten of the studies (62.5%) used achievement tests to collect data from the participants (Barrett & Fish, 2011; Bulgren, J. A., Deshler, D. D., & Lenz, B. K., 2007; Frank, 1978; Gaudreau, 1992; Gliga & Flesner, 2013; Leshowitz, et al. 1993; Liptrap, 1998; Mastropieri, M. A., Scruggs, T. E., Norland, J.J., Berkley, S., McDuffie, K., Tornquist, E.H., et al., 2006; Nurse, 1995; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk, et al., 2008; Smith & Cage, 1998). Two of the studies (12.5%) used observation data (Batchelder & Alexander, 2012; Moran & Jarvis, 2001). Three of the studies (18.75%) used problem-solving tasks to collect data from participants (Bogard, Liu, & Chiang, 2013; Horgan, 1987; Rifner & Feldhusen, 1997). One study (6.25%) used theoretical analysis of chess rankings to collect data from participants (de Groot, 1978).

3.2.3 Findings of the studies

The findings of the 16 research studies in this meta-synthesis can be summarized as follows.

1. Students who play chess, either in chess clubs, or during the formal school day achieve better in mathematical computation and reasoning and reading comprehension, as well as problem-solving skills. Formal chess instruction can take place as a specific class or replace one mathematics class per week and still produce higher mathematics achievement without loss of content knowledge.

2. Chess instruction does not have to occur for great lengths of time to show increases in achievement scores. In as little as ten weeks, students' achievement gains can be measured. Chess instruction does not have to occur in a formal manner to result in increased achievement.

It can be done in a club setting with similar gains as a formal class.

3. The game of chess promotes not only gains in achievement, but increases problem solving and analysis skills. The high level of problem-solving required to play chess promotes these gains.

3.3 Emergent Themes

Six themes emerged from my analysis of the articles in this meta-analysis. These emergent themes or clusters include: (a) chess instruction promotes critical thinking skills; (b) early chess instruction promotes greater gains in critical thinking skills; (c) Mathematics and Science achievement increases with implementation of chess education; (d) students with learning disabilities experience achievement gains with chess instruction; (e) skills learned in chess can be generalized to other content areas; and (f) perseverance is learned and is necessary for growth in chess skill and therefore promotes academic achievement and problem-solving. These six themes and their formulated meanings are represented in Table 3.

Table 3

Theme Clusters	Formulated Meaning
Chess instruction promotes critical thinking skills.	• Children who learn chess learn it from a generalist's perspective, adults, from a specialist's perspective. • Critical thinking taught in chess seems to transfer to visual dynamics. • Chess skill does not have to be high, but increasing in order to see critical thinking skill gains. • Cognitive development is enhanced by chess play, in addition to achievement and standardized testing. • Chess skills translate into organizational skills and ability to think flexibly. • Complex tasks in chess instruction teach students to revisit earlier experiences and learning, to reassess learning, and to make decisions about future action. • Collaborative learning such as in chess learning, increases motivation and ability to think critically. • Novices in critical thinking require more support as they learn, but

	less as they become more proficient.
Early chess instruction promotes greater gains in critical thinking skills.	• Young students learn chess in a more general manner and are more able to link these skills to other content areas. • Adults learn chess skills in a specialist manner and are less able to transfer skills to other learning skills. • Students in elementary grades, who learned chess, made gains in achievement and critical thinking skills in a short period of time, as little as ten weeks. • Students are able to make greater gains in critical thinking skills and achievement in upper elementary grades than middle school grades. • The greatest gains in critical thinking skills are made in upper elementary.

Mathematics and Science achievement increases with implementation of chess education.	• Students who engage in chess instruction make greater gains in mathematical and scientific reasoning than their peers. • Computational achievement gains tend to be the greatest as a result of chess instruction. • Cooperative learning skills are increased, as is motivation, which leads to greater science achievement gains. • Probability and statistical reasoning increases with chess instruction. • Students receiving special education services need explicit instruction in the connection between skills learned in chess and how they apply to specific content areas. • Chess instruction can replace mathematics instruction at least one time per week without affecting mathematics achievement. In fact, mathematics achievement increases despite less content instruction. • Gifted students make greater gains in achievement, when exposed to chess instruction, than their typical age-peers who also receive chess instruction. • Mathematics and science achievement increases with chess instruction within the school day or in a club setting. • Students who receive chess instruction experience an increase in positive self-image, which seems to translate into increased achievement. • Teaching students who experience a learning disability to visualize complex routines can increase their ability to think more complexly in specific content areas.

Students with learning disabilities experience achievement gains with chess instruction.	• Students receiving special education services made greater gains in achievement when given chess instruction, than their regular education peers. • Chess skill level is not an indicator of gains in achievement. • Achievement gains for students who experience a learning disability can be seen in a relatively short period of time. • Achievement gains can be made through direct chess instruction in school or through instruction in a chess club environment.
Skills learned in chess can be generalized to other content areas.	• As chess skill increases, so does achievement in mathematics and science. • Reading comprehension skills seem to also increase as a result of chess instruction. • Students are able to concentrate for more sustained periods of time as a result of chess instruction. • Sustained concentration leads to increases in achievement. • Chess instruction done in a game play manner, helps increase a student's sense of wellbeing and thus academic achievement. • In middle school students, chess instruction was correlated to an increase in motivation to learn in other content areas.

Perseverance is learned and is necessary for growth in chess skill and therefore promotes academic achievement and problem-solving.	• Complex problem-solving is necessary to play chess. This requires perseverance. • Increased motivation as a result of chess instruction increases middle school students' willingness to persevere on complex science tasks. • Chess is a complex game to learn. Students who continue to attend chess club sessions, learn perseverance as they learn chess skills. • Chess instruction increases students' ability to solve more complex mathematical problems, showing an increase in skill and perseverance.

4. Discussion

In this section, I have summarized the emergent themes from my analysis of 25 articles included in this meta-synthesis. These emergent themes were then connected to my own practices as a special education teacher.

4.1 Chess instruction promotes critical thinking skills

The research shows that chess instruction increased critical thinking skills on the order of 15 to 20 percent gains on measures of critical thinking skills. These critical thinking skills seem to translate to visual dynamics, which are useful in a number of content areas. Gains in critical thinking are seen in a relatively short period of time. Chess skills do not have to be high, but the process of engaging in the learning and problem-solving tasks associated with chess, enhance the brain's ability to think more globally and through more steps than students who do not play chess. Organizational and flexible thinking are also increased with chess instruction. This translates into more creativity in students' work.

When students are dealing with complex tasks in chess play, they find it necessary to return to prior moves to assess for future moves. This is also seen in academics where students engaged in complex tasks. Looking back at prior learning helps students make decisions about future learning or what they need to do to complete a complex task. Chess instruction canincrease students' ability to process information in this manner. More scaffolding is required for students while they learn these processes, but over time they become more independent and able to think critically.

One of the greatest critical thinking gains is the ability of students to see several moves down the line in a chess strategy. This thinking translates into students' ability to think through multiple steps in a mathematics equation or scientific process. This allows greater problem solving. It also in the brain using less working memory to complete tasks than when it has to work through each step individually.

Teaching chess as a critical thinking vehicle is very useful for students who experience learning disabilities. These skills are often lacking in these students. Students with a specific learning disability that affects their mathematics understanding find multiple-step equations and

problems to be daunting. However, they seem to be drawn to the game of chess. This provides them with highly motivational learning and offers a hands-on experience for developing critical thinking skills.

Direct connections between skills learned in chess and those needed in mathematics or science may need to be articulated for students who experience a specific learning disability. For example, students learn three-step checkmates. This can be correlated to looking at the process for multi-step equations. Class discussions regarding this connection are invaluable and a necessary part of using chess as a critical thinking tool in special education.

Chess instruction in my classroom can serve as a vehicle to teach students these important critical thinking skills. I can help students not only learn the game of chess, but also correlate the skills to their academic learning as well. I find that when I explicitly outline the connections between concepts, my students have a better grasp of fundamental understandings than when I expect them to make the connections themselves. This scaffolding is very important, especially for students who experience a learning disability or who have significant gaps in their learning. I find that I have to scaffold in a similar fashion in my mathematics classroom, so it follows that this would be necessary pedagogy in my chess instruction as well.

4.2 Early chess instruction promotes greater gains in critical thinking skills

Children can perform highly complex tasks as well as adults, but they do so in a different manner. When children are exposed to highly complex tasks such as those associated with chess play, they look at the challenge from a global perspective and then move to a more detail oriented approach. This allows for more flexible thinking to occur. When adults learn highly complex tasks, they tend to start at the detail-oriented approach and cannot always think

as flexibly. Therefore, the earlier the implementation of chess instruction, the more flexibility students gain in their critical thinking ability.

In addition to being able to think globally, students make greater gains at certain stages of their academic development. Students in third grade do not make significantly greater gains in achievement as a result of chess instruction. However, students in fifth grade make statistically significant gains over their peers who do not receive chess instruction. It appears that there is an opportune time, in these early years of education, where students are developmentally able to learn the complexities of chess, which then translates into achievement gains. However, this developmental window is not open for long. Teachers must take the opportunity to exploit students' readiness to learn when it is the most opportune for them, and thus chess instruction should begin in the upper-elementary years.

As a middle school special education teacher I cannot teach children at a very young age. However, sixth grade is still a formative developmental time in a child's life. Although, this year I teach eighth grade, I work with a general education teacher who teaches a chess elective. In this way I can work and plan instruction in a vertical manner to ensure that students receive chess instruction early. I can also assist other mathematics teachers in their planning and connecting chess to mathematics and science instruction. It is important to connect the skills learned in both content areas for students.

I also teach chess club for more intensive instruction. This activity is offered within a program for low socio-economic students. This allows students who may not have exposure to chess to receive chess instruction along with assistance in their schoolwork. Hopefully, this will have a positive effect on students' achievement beyond the enjoyment of the game.

I would like to see chess integrated into mathematics instruction formally, in our school. I

hope to be able to share this research with administrative staff in the hopes that it can be incorporated more widely. A more formalized approach to chess inclusion in the curriculum will ensure that teachers instruct with fidelity and ensure that all students are exposed to this important aspect of learning.

4.3 Mathematics and Science achievement increases with implementation of chess education

Students who participate in chess instruction, as part of their school day, experience increases in their mathematics and science achievement. In addition, chess instruction that replaced one mathematics lesson a week did not negatively affect mathematics achievement. In fact, it increased even with the reduced direct instruction in mathematics. The implication of this is very important. Chess instruction has a profound effect on the ability of a child to think mathematically. It may be said that direct instruction that fosters critical thinking is more beneficial than direct instruction in content.

In addition, chess instruction is seen as game play more than it is seen as learning. For this reason, students are motivated to learn chess. This motivation seems to foster a sense of well being in students that translates into motivation to learn in more formal academic environments as well. It also results in more productive use of collaborative learning time in the content classroom.

I have found that it is true that instruction that fosters critical thinking is beneficial to students as it permeates all content areas. If I attend to the explicit processes of problem solving and offer specific critical thinking skills instruction to students, they start to make cross curricular connections. They also start to make connections in my mathematics classroom. I am able to teach more global skills that afford students the ability to solve mathematics problems as well. This type of instruction ensures that students learn skills to relate their content learning

to new contexts. It becomes a vehicle to think through any type of problem, which increases achievement overall.

4.4 Students with learning disabilities experience achievement gains with chess instruction

Students in special education classes were found to experience greater gains in achievement than their general education peers. One study, included in this meta-analysis, showed special education students' achievement levels rise from well below those of their general education peers to equal or greater after the implementation of a chess instruction program. The implementation of chess instruction was short-lived, which indicates that gains can be made without a huge time cost. In addition, the level of chess skill was not an indicator of the achievement gains made, but the fact that students were involved in direct learning of the game and its tactics was beneficial.

Chess instruction was found to be beneficial both as direct instruction within the school day and through chess clubs after the school day. However, more students attended formal chess lessons than those who attended chess clubs. In addition, students tend to be present for instruction within the school day more regularly than in a club format. It was found that in the chess club format, those who attended regularly were found to make gains, not those who were sporadic attendees. Therefore, it can be said that consistent and regular chess instruction is necessary to see achievement gains in students. This would be more important for students who experience a learning disability as it is often necessary to offer more repeated instruction in a skill in order to see mastery.

As a ranked chess player, it is important to me to increase my skill as a chess player. However, this meta-analytic process has taught me that it is not the rank that is important, but the explicit instruction in the game of chess and the properties of the game that are important to

increasing student achievement. The important aspects of chess, to teach students, are the patterns involved in tactics and requiring them to think through multiple-step checkmates and sequences. There are many different opening patterns and methods of play that can enhance a player's chances of winning a game of chess. These patterns and tactics stretch the mind to think through multiple steps and multiple responses to a particular position. This is where the training in critical thinking is most beneficial. I need to keep this in mind when I am planning instruction and in planning my expectations for students' performance in chess. In this case, it is about the process and not the product. Also, it is important to offer repeated and consistent instruction in chess in order for students who experience a learning disability to receive adequate exposure to the content to ensure mastery.

4.5 Skills learned in chess can be generalized to other content areas

All research studies included in this meta-analysis showed increases in achievement in not only chess, but in the content areas of mathematics and science. In addition, it was noted that visual-spatial reasoning was enhanced, along with the ability to critically analyze problems. Quantitative reasoning and understanding probability were also specifically enhanced through chess instruction. Concentration skills are increased when students learn to play chess. They are able to focus on the game as well as learning for a more extended period of time. Students can also grapple with more complex tasks as a result of learning the intricacies of chess.

Chess instruction also resulted in an increase in reading comprehension. Students who receive chess instruction are more able to concentrate for extended periods of time as well as persevere in decoding reading passages. This leads to an increase in reading comprehension and thus an increase in reading achievement.

Students in my class need intensive instruction in chess as well as content. It will be

interesting to see, over time, if chess instruction is able to help students make greater gains, faster than a hands-on replacement or remediation curriculum. Differentiated instruction is important, but it remains to be seen if gains are greater or faster using differentiated instruction or to replace some content instruction with chess instruction. This is an area for further study.

4.6 Perseverance is learned and is necessary for growth in chess skill and therefore promotes academic achievement and problem-solving

In order to learn and/or master complex chess strategies, students must persevere through multi-step analyses of positions and many options for their next move. This requires patience and perseverance. This perseverance is necessary in order to assess all possible moves associated with a particular position on the board. Perseverance such as this also translates to the academic realm as well. Students are not only able to think through more complex academic tasks, but are more willing to persevere for the time it takes to be successful at these tasks. This was seen most prominently in middle school students. They were more productive and collaborative in completing complex scientific tasks, which increased achievement.

My hope is to see this perseverance translate into mathematics for my students. Many of my students are so disenfranchised with the school system and have experienced repeated failure in mathematics, that they are not motivated to learn and unwilling to persevere on the learning tasks required to master mathematical concepts. If I can increase motivation to learn through chess play, my hope is that they will be able to transfer this willingness to persevere into mathematical tasks. An increase in ability to solve mathematical tasks and the willingness to persevere to complete these tasks will, hopefully, afford students success in mathematics that they have not recently experienced. If I can increase success in mathematics, then hopefully students will become more motivated to learn.

5. Conclusion

The findings of this meta-synthesis show a clear connection between chess instruction and an increase in critical thinking skills and academic achievement for students. The evidence shows that gains in achievement and critical thinking skills can be seen after a relatively short period of time. This indicates that students can experience success at any point in their academic career. However, upper elementary seems to the most opportune time to see gains. This may be due to developmental readiness or there may be other factors involved. More research is warranted in this area.

Gains in academic achievement are seen in mathematics, science, and reading in particular. Other content areas are not readily assessed using standardized tests, so these were not explored in the studies found for this meta-synthesis. Mathematics achievement gains were seen specifically in computation, quantitative reasoning, and probability and statistics. Science gains were seen in critical thinking and motivation to learn. Reading comprehension gains were also associated with chess instruction.

The findings of this study indicate that critical thinking ability is crucial for academic achievement. This can be taught in several ways. The game of chess appears to be a vehicle for teaching these skills at a high level in a relatively short period of time. Chess appears to result in academic gains for students of all achievement levels and in several content areas.

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