Chess as an educational tool and

how it can improve the mathematical skills of school students

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Abstract

The systematic literature review presented here records those studies which took place with the goal of investigating improvement in the mathematical skills of students from the use of chess as an educational tool. From a total of 53 studies (another 52 with goals in addition to mathematics were excluded), 12 were finally chosen which fulfilled the following additional conditions: i) having been published exclusively in a scientific journal and ii) having been carried out during school hours and divided using specific individual criteria which are referred to analytically. The study concludes that with the aid of chess, teachers can help students solve mathematical and other types of problems, while suggesting areas which require further investigation.

Key words: Systematic literature review, school chess, mathematics, problem solving, student benefit, educational tool

Introduction

With the passage of time, an increasing number of young children can be observed taking an interest in chess. Its former perception as an elite activity and the class distinction between chess players has gone for good. The association of chess with the aristocracy is reinforced by the expensive and exquisitely carved chessboards of the Middle Ages (History of Chess, 2016). A recent study has found that the chess community, consisting of more than 605 million adults who regularly play chess, is one of the largest in the world. (Dennys, 2012). Today parents encourage their children to play chess, and many recognise the educational benefits that can be derived from it. The contemporary literature offers a wide range of studies which have been carried out worldwide on the topic of chess as an educational tool. Since 1893, when the first study of chessplayers who played without sight of the chessboard (Blindfold chess) was carried out with the aim of exploring their memory skills (Binet, 1966), a vast number of studies have taken place all over the world, chiefly investigating the benefits that may be derived from introducing chess into the education system.

The presentation of the current research will be as follows: first, the methodology followed during the procedure of investigating the sources of the systematic literary review; second, the research data, organised comparatively based on the place where the studies were carried out; and finally the conclusions, based on the summary of the 12 peer reviewed studies chosen. The presentation is completed with the final conclusions and proposals for further research.

Chapter 1: Systematic Literature Review

1.1 Theoretical Framework

The existence of many of publications on the topic to be investigated and the relatively large mass of data may hamper the researcher's attempt to discover and evaluate useful and valid data. An attempt is made through reviewing the literature to distinguish studies with common goals and conclusions. These secondary publications may be divided into descriptive and systematic. The systematic reviews differ from the descriptive in that they constitute a body of research carried out on the basis of specific scientific methodology. The researcher is required to clarify the research questions, to design the research protocol, determining the criteria for searching and selecting the material which will be studied, to designate criteria for inclusion or exclusion of the primary studies and to seek out the papers to be included in the analysis, and the evaluation of which will lead to the appropriate conclusions being drawn (Smelser & Baltes, 2001; Wright, Brand, Dunn & Spindler, 2007; Centre for Reviews and Dissemination, 2009; Gwen, 2010; Evidence for Policy and Practice, 2010; PubMed Health, 2011; Gough, Oliver & Thomas 2012; Systematic review, 2016).

1.2 Formulation of Research Question

The first step in the systematic review was to formulate a clear scientific hypothesis regarding the connection between the variables studied and the frequency with which an outcome appeared, while also taking into account the possible existence of interpolation or even categorical variables (Higgins, 2009).

In this scientific procedure, the initial question put forward as a scientific hypothesis was: "Can chess constitute an educational tool which will help the student both in mathematical and academic knowledge as well as in character and cognitive and social abilities, and if so, is that influenced by the place where the lessons take place?" This question was refined and finally formulated as: "Can chess constitute an educational tool which will help the student with mathematics, problem solving, geometry and specifically with spatial concepts when it is taught during as part of the school curriculum?"

1.3 Objectives of the Systematic Literature Review

The systematic literature review and its subsequent meta-analysis is an investigation into research found concerning the possible benefits which may occur after chess is taught to school students, chiefly in terms of their mathematical skills such as problem solving, arithmetic and geometric concepts, spatial concepts and so on.

Our study had three basic objectives:

i. The first objective was to evaluate the total degree of influence and the benefits that could come about after chess instruction, either by comparing an experimental and a control group or with the use of other scientific tools.
ii. The second objective was to comparatively assess the criteria used to implement the studies and whether these were sufficient for the needs of the research questions.
iii. The third objective was to discover whether gaps in the research exist, which could constitute a potential motivating factor for future studies.

1.4 Methodology of Literature Review

In order for the literature review to be systematic, the careful design of the present research followed a specific methodology which was based among other features on principles laid down in the Cochrane guide for researchers of organisations (Higgins, 2009) and on Petticrew and Roberts (2006). The protocol for the systematic review was determined with clarity, and the criteria for inclusion or exclusion of the various studies were subsequently applied precisely, until finally the most suitable studies emerged.

1.5 Criteria for Inclusion and Exclusion of Studies

The systematic literature review of the current study was limited to peer reviewed journals as the required and exclusive source of data. Studies presented at conferences were excluded if they had not also been presented in a peer reviewed journal, even if they had been jury approved. Similarly, studies which had only been presented in chess pages and magazines as well as those which were integrated

into books were not used. In order to carry out the fullest research possible, the contribution of a large number of researchers was sought so as to establish whether or not published studies by them existed.

The basic criterion in choosing studies was laid down as being that chess was the main research tool, while it was decided that the prescribed objective must at least include mathematics; at the same time studies carried out outside of the school timetable were also excluded. Of the studies which have been found, only those were recorded and evaluated which made reference (either as a cause or a result, chiefly or in part) to mathematics (whether as analysis of problems, geometry or simply as arithmetic). Even though science and the evaluative tools are developing and being modernised, no time limitation was laid down, as it was decided that not only chess but also the research goals are timeless. However, the majority of studies which meet the criteria are from the last ten years, with the exception of that from 1997. In older studies which were not evaluated, a difference was noted concerning the choice of age of the subjects (more recent studies chose younger students); however, this was not considered to be a sufficient cause to exclude older studies. Corresponding to this tendency, the oldest students took part in the oldest of the studies presented here (Smith & Sullivan 1997). The most recent studies were carried out with the participation chiefly of primary school or even kindergarten students. Difficulty in understanding studies in languages other than English restricted the range. In Greek only one study of chess has taken place; however, this relates it to art, and specifically to painting (Sfikas, 2007). Also excluded were those studies which approached the topic of our research from a purely theoretical viewpoint; only empirical studies were included.

1.6 Search for Relevant Bibliography - Selection of Studies

The discovery of all the relevant published studies which have been included was established analytically on the basis of the criteria laid down above, so as to facilitate repetition or meta-analysis by other researchers as well as evaluation of external validity.

1.6.1 Search strategy. The literature research was carried out systematically and analytically using various sources of information, such as internet search engines, internet chess pages, references to published dissertations, Greek and

foreign bibliographies, as well as studies by academic, state or private organisations which for various reasons have not been published, as well as references to chess books. After the collection of a large number of studies, both peer reviewed and not, the references given by these studies were collected and a thorough study was carried out based on these. The search results were also cross checked with the meta-analyses of Nicotera and Stuit, (2014) and Sala and Gobet, (2016). Personal contact was also made with a large number of researchers, some of whose articles are available on the internet while others are not.

1.6.2 Key words. A wide range of key words were used, with the aim of finding the greatest possible number of studies. The words were used either autonomously or with the help of operators as required by the databases. Particularly helpful were the meta search engines supported by Summon. The key words used were: Chess, Math, Geometry, Research, School, Method, Skills, Problem solving, primary or elementary School and education. The words were usually set to "all fields", without omitting modifications specific to the database. In some cases parts of words were set as key words, and in a large number the research was undertaken with the assistance of the original author.

All of the sources researched are included in the following tables:

Table 1

General research pages

General Research pages	
Academic Search Premier	Open Access to Science Information
Academic/Enrichment - Harvard Family Research	Open archives
American Scientist	ProQuest Dissertations & Theses
Open Access	PsycINFO
Library of the Pedagogical Institute	Research in the Schools
Chess'n Math Association	SAGE
Chinese University of Hong Kong	ScienceDirect
Current Issues in Education	Scopus
EconLit	Southern Connecticut State University
Education Research Complete	Stanford Encyclopedia of Philosophy
Education UK - The Independent	Startsida | NCM:s och Nämnarens webbplats
Educational Technology & Society	Taylor Francis Online

E-Journals	Teaching Children Mathematics
Elsevier	The British Psychological Society
ERIC	The Christian Science Monitor
Essays In Education	The Mathematics Enthusiast
National Archive of Doctoral Theses	The New York Review's University Press
National institution of Research	The New York Times
Εθνικό και Καποδιστριακό Πανεπιστήμιο Αθηνών	The Scottish Government
Google Scholar	Univercity of Pennsylvnia
HLink	University of Haifa
International Journal of Educational Investigations	University of Sydney
International Journal of Special Education	University of Birmingham, UK
Journal of Experimental Child Psychology - Elsevier	University of Houston
Journal of Learning Disabilities	University Of Minnesota
Kluwer Academic Publishers	University of Pretoria
Law Journal Press	University of Tampere
Library Auth	University of Texas at Dallas
Manchester Metropolitan University	Web of Science–Social Science Citation Inde (SSCI)
Maths for kids	World Conference on Educational Sciences
National Council of Teachers of Mathematics	WorldCat
Open Access Articles	Ministry of Education and Religious Affairs

Table 2

Chess pages

Chess pages	
Afterschool Alliance	Florida Afterschool Network
Ajedrez 21	Ho Math Chess
Articles - ICCS - Chess Academy of Armenia	International Conference "Chess in Schools"
Berkeley Chess School	International Society for Chess Research
Broward Chess Club	It's Our Move
Chess & Bridge	Kasparov Chess Foundation

Chess and Mathematics - London Chess and Education	Kasparov, Chess Foundation Europe
Chess at Three	Math + Chess
Chess for Success	National Scholastic Chess Foundation
Chess in Schools & Communities	New in Chess
Chess in Schools and Communities	Ohio Chess Academy
Chess in Schools and Communities	Child and Chess
Chess Magnet School Curriculum	Renaissance Knights Chess Foundation
Chess Palace Program	Skakistiko
Chess Program – Univ. of Texas, Dallas	Success Chess
Chesshouse	Susan Polgar Foundation
Chess-in-the-Schools	The American Chess Foundation
Chesskid.com	The Chess Academy|Math and Reading Data
Edutech Chess: Why Chess?	The US Chess Federation
Greek Chess Federation	Think Like a King
FirstMove	World Chess Federation

1.7 Criteria for Choice of Presentation

In every field of scientific research, the term variable is a particular observational tool determined in the transitional stage between formulating a hypothesis and the observations relating to it, namely, its authentication (Variable, 2015). According to Argyrous (2005), a variable is every characteristic or property which allows more than one value. The association of chess with multiple variables constituted a criterion for specific classification.

As stated above, all of the studies chosen have at least chess and mathematics as variables. In eight studies mathematics is the only variable (apart from chess), in two problem solving and geometrical concepts, while in one only spatial concepts. One study also controls other academic concepts apart from mathematics, such as reading and writing.

Those studies whose sole criterion is mathematics constitute a sub-category, which approaches students' Logical-Mathematical Intelligence, in contrast with those which also approach Verbal Linguistic Intelligence, and constitute another sub-

category.

Howard Gardner's (1983) theory of the existence of multiple forms of human intelligence proposes indicators of intelligence which are not restricted to verbal-linguistic or logical-mathematical intelligence, but also to intrapersonal and interpersonal, musical, kinaesthetic and others. Since the existence of mathematics as a variable was regarded as essential for the studies chosen, and a large number of studies investigating other skills were excluded, the current presentation investigates primarily logical-mathematical intelligence.

1.8 Peer Reviewed Journals for Publication of Studies

The 13 studies presented here were published in the following journals.

Table 3

Chess and Mathematics Peer Reviewed Research Journal

Chess and Mathematics Peer Reviewed Research Journal
Aarhus University and IZA
Academic Journals
Early Child Development and Care
Educational resources information center (ERIC)
Eurasia Journal of Mathematics, Science & Technology Education
International Journal of Educational Investigations
International Journal of Special Education – three studies
Quaderni di Ricerca in Didattica Mathematics
Sage Open
The Mathematics Enthusiast TMME)

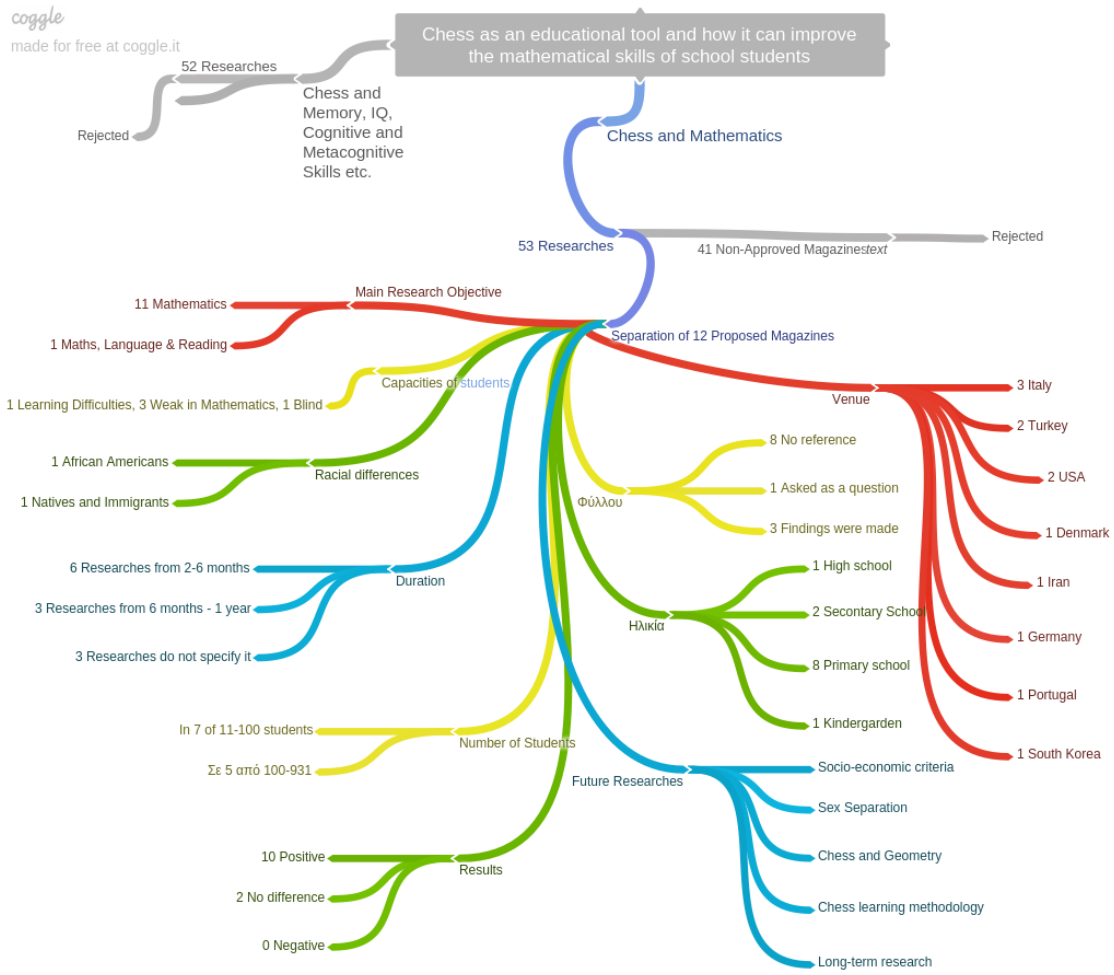

Diagram 1. Approved studies

Chapter 2: Studies Worldwide: Classification based on objectives

2.1 Introduction

The studies are classified according to their individual objective - variables. In the presentation reference is made to the number and the age group of the students who took part, as well as the school classes, the number of hours and the results, the type of school (classical, special education), the duration and finally the place and time that the study was carried out.

With the exception of the studies in Seoul in 2002 (Hong & Bart 2003) and to some extent in Louisiana in 1997 (Smith et al. 1997), the remaining eleven came to positive conclusions. Student improvement based on the predetermined objectives had varied levels but was always positive, regardless of study duration.

In most cases one teaching hour of mathematics was replaced for the experimental groups by one hour of chess. In Iran 2013-2014 the chess lesson lasted 2 hours (Khosrorad, Kouhbanani & Sani, 2014).

In 1997 in Louisiana (Smith et al. 1997), 2008-2009 in Texas (Barrett & Fish, 2011) and 2012 in Turkey (Aydin, 2015) junior high school students participated, while in the remaining studies primary school students and in 2012 in Turkey kindergarten students (Sigirtmac, 2011).

The duration of all of the studies was between 2 months and 1 year, and the number of students participating varied between 11 in the smallest group and 931 in the largest. The age range of the students was between 5 and 17 years.

3 studies were carried out in Italy, 2 in Turkey, 2 in the USA and the remaining 5 in different countries.

All of the studies featured an experimental group and a control group with the exception of those in Louisiana (Smith et al. 1997) and in Portugal (Ferreira & Palhares, 2008). In half of the studies the choice of student participants was random (Khosrorad et al., 2014; Hong et al., 2003; Sala, Gorini, A. & Pravettoni, 2015; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk & Schwarz, 2008; Barrett et al., 2011; Trinchero & Sala, 2016).

The studies were carried out from 1997 to 2014, while publication was between 1997 and 2016.

The researchers' objective was to investigate the improvement which students

could attain through learning chess, whether that was “compulsory” or optional during teaching hours. The findings to date suggest that the researchers’ interest was motivated by academic concerns, in contrast to some unpublished studies which were in response to negative conclusions from international studies regarding the level of student achievement, especially in mathematics (good examples being Zielinska, 2014; Krämer & Filipp, 2013).

2.2 Research Questions

In the majority of studies the main question posited was whether students could perform better at mathematics with the aid of chess (Aydin, 2015; D‘Eredità & Ferro, 2011; Gumede & Rosholm, 2015; Khosrorad et al., 2014; Sala et al., 2015; Scholz et al., 2008; Smith et al. 1997; Trinchero et al. 2016; Hong et al., 2003); in some cases the question was limited more specifically to the solution of arithmetic or geometric problems (Ferreira et al., 2008; Sigirtmac, 2011). In Portugal problem-solving was further investigated in relation to age, gender, school class and the mathematics level of the students (Ferreira et al., 2008)

2.2.1 Mathematics. The study carried out between 2008 and 2009 in Texas, USA by Barrett et al. (2011) involved a small sample of 31 junior High School students (15 in the experimental group and 16 in the control group). The programme lasted 30 weeks), during which time one hour of mathematics per week was replaced by one hour of chess for the experimental group.

An experimental programme carried out in Turkey in 2011 focussed chiefly on spatial concepts, orientation in space, geometry, and possible differences between the two genders that might be observed from teaching chess to pupils aged between 5 and 6 years. 100 pupils (50 boys and 50 girls) took part in the study, half of whom were learning chess. The results were analysed using the Mann-Whitney U test (as referred to in Sigirtmac, 2011), which revealed a significant superiority in all fields for the experimental group, and no difference between the two genders (Sigirtmac, 2011).

Trinchero (2013) and Trinchero et al. (2016) have carried out two large-scale studies in Italy. Unfortunately, the longest-lasting study to have taken place so far, between 2005 and 2011 (Trinchero, 2013) has not yet been published, and consequently reference cannot be made to it, in contrast to his second study, which

was the largest even though it lasted only 6 months. 931 pupils from 20 schools took part, divided into two experimental groups and one control group. In one experimental group 320 pupils were taught chess by 18 chess players, while in the other 220 pupils were taught chess by non-chessplaying professional teachers. The control group consisted of 23 teachers and 391 pupils (Trinchero et al., 2016)

In Portugal in 2008, 437 pupils from the 3rd to the 6th class of primary school took part in a study where it was observed that chess corresponded particularly with solving problems with geometric and arithmetic motifs, with better results in arithmetic rather than geometry (Ferreira et al., 2008).

The study of 53 students with learning difficulties in Saxony in Germany 2004 also found significant improvement in mathematics of those students belonging to the experimental groups (Scholz et al., 2008).

In Iran it was found that chess can improve students' skills such as memory, perception, attention and logical thought, as well as helping them in problem solving both in mathematics and more generally (Khosrorad et al., 2014).

The only study not to find particularly significant student improvement in mathematics took place in 1997 in Louisiana using tools of the Test system (GEFT) (as reported in Smith et al. 1997) with the aim of investigating analytic methods of perception of 11 Afro-American students (4 boys and 7 girls). It was carried out through 50 hours of chess teaching and parallel competitive application, and concluded that there was a proportionately greater improvement in the girls' abilities in contrast with that of the boys (Smith et al. 1997).

2.2.2 Mathematics, writing and reading. Research was carried out in three primary schools in Seoul in 2002 with the participation of 38 students aged between 8 and 12. The students were randomly divided into two groups. The control group was formed of 15 boys and 5 girls with an average age of 9.74 years, while the experimental group consisted of 12 boys and 6 girls with an average age of 9.71 years. Three students in each group had learning difficulties. This is the only one of the studies known to date which concluded that there was no difference between the students of the two groups, either at academic level or at the level of cognitive psychology (Hong et al., 2003).

2.3 Division by Student Ability

In Saxony, Germany, the study was carried out with 53 students with learning difficulties (Scholz et al., 2008), while in 2008-2009 in Texas, USA (Barrett et al., 2011) and 2002 in Seoul (Hong et al., 2003) the students were weak in mathematics. The students in Iran (Khosrorad et al., 2014) were generally weak in academic knowledge, while in Turkey 26 blind junior high school students participated (Aydin, 2015).

To summarise: due to the fact that the studies took place with students with special needs, understandably a small sample was chosen. We note/observe that even in the case of persons with special needs, chess may contribute to the goal of improving their mathematical skills.

2.4 Division by Place and Student Age

2.4.1 Junior and senior high school students. A study carried out in Louisiana in 1997 aimed to investigate analytic methods of perception of 11 Afro-American students (4 boys and 7 girls) aged 16-17 (Smith et al. 1997). The study which took place in Texas, USA by Barrett et al., (2011) involved a small sample of junior high school students (15 in the experimental group and 16 in the control group). In Turkey 26 blind junior high school students participated in a study. 14 students (9 boys and 5 girls) participated in the experimental group and 12 (8 boys and 4 girls) in the control group (Aydin, 2015). In Sicily, Italy D'Eredità et al. (2011) carried out a study between 2008 and 2010 with the participation of 45 students aged 11 (10 in the experimental group and 35 in the control group).

2.4.2 Primary school students. In 2002 a study was carried out in three primary schools in Seoul, with the participation of 38 students aged 8-12. The students were randomly divided into two groups. The control group consisted of 15 boys and 5 girls with an average age of 9,74 years, and the experimental group consisted of 12 boys and 6 girls with an average age of 9,71 years. Three students in each group had learning difficulties (Hong et al., 2003). In Saxony, Germany, in 2004, 53 students aged 10 with learning difficulties were divided into a control group of 22 and an experimental group of 31 (Scholz et al., 2008). In Portugal in 2008, 437 students from the 3rd to 6th classes of primary school participated (Ferreira et al., 2008). In a study carried out in Iran, the 20 participants aged 9-12, were separated into two equal groups, half in the experimental group and half in the control group (Khosrorad

et al., 2014). One of the largest studies took place in Northern Italy with the participation of 560 students (309 in the experimental group - 169 boys and 140 girls - and 251 in the control group - 116 boys and 135 girls) aged 8-11 years old (Sala et al., 2015). The largest study so far took place in Italy from December 2013 to May 2014. 931 students from the 3rd to 5th classes of 20 primary schools were divided into two experimental groups (differing by teacher) and one control group (Trinchero et al., 2016). In Aarhus in Denmark 482 students from the 1st to 3rd classes of primary school were divided into an experimental group of 323 and a control group of 159 in a study conducted by Gumede et al. (2015).

2.4.3 Kindergarten students. In Turkey in 2011 a study was carried out with the participation exclusively of kindergarten students (5-6 years old). 100 students participated (50 boys and 50 girls), half of whom were taught chess (Sigirtmac, 2011).

Summary: The studies confirm that in recent years younger samples are chosen. That is considered reasonable, as with the passage of time younger and younger children are taking up chess. Today 27 children born in 2012, 210 in 2011 and 1300 in 2010 are registered athletes in various chess federations, confirming this tendency (Fide, 2016).

2.5 Division by Number of Students

In 7 studies fewer than 100 students participated, while in 5 more than 100. The Louisiana study had the smallest number of participants with only 11 students (Smith et al. 1997). 20 participated in Iran (Khosrorad et al., 2014), 26 in Turkey (Aydin, 2015), 31 in Texas (Barrett et al., 2011), 38 in Seoul (Hong et al., 2003), 45 (with only 10 in the experimental group, as emphasised by the researchers themselves) in Agrigento (D'Eredità et al., 2011) and 53 in Saxony (Scholz et al., 2008).

The studies with the largest number of participants were in Italy with 931 students (Trinchero et al., 2016), in Northern Italy with 560 (Sala et. al., 2015), in Aarhus with 482 (Gumede et. al., 2015), 437 in Portugal (Ferreira et al., 2008) and 100 in Turkey (Sigirtmac, 2011).

Summary: A significant distribution may be noted in the sample used. It should further be noted that 5 of the smaller studies took place with the participation of students with special abilities, while in the Louisiana study the sample was limited to

Afro-Americans. As the size of the sample increases, there is a corresponding decrease in the error of assessment, and consequently also the area of significance. As the sample size increases, both the estimation error and the significance range are reduced. When the level of significance decreases, the area of rejection decreases and the area of acceptance increases (Green, Tull & Albaum, 1988; Kerlinger, 1994; Norris, 2005; QuickMBA, 2010; Entepreneur, 2016).

2.6 Division by Duration of Programme

The study with the shortest duration took place in Louisiana in 1997 (Smith et.al. 1997) and lasted 2 months. The studies in Seoul (Hong et al., 2003), in Texas (Barrett et al., 2011), in Turkey (Aydin, 2015) and in Northern Italy (Sala et. al., 2015) all lasted 3 months. The most recently published study in Italy lasted 6 months (Trinchero et al., 2016), while those in Aarhus, Denmark (Gumede et. al., 2015) and Agrigento in Sicily in Italy (D'Eredità et al., 2011) lasted 9 months. The studies with the longest duration, one year, were those in Saxony, Germany (Scholz et al., 2008) and in Iran (Khosrorad et al., 2014). Ferreira et al. (2008) refer to a two-year study, without, however, clarifying this. Sigirtmac (2011) in Turkey does not clarify the duration of his programme.

Summary: It is observed that positive results may also be found after the application of studies of shorter duration. Naturally, it should be stressed that the studies with shorter durations also concerned a smaller sample size. The study with the largest number of student participants had a duration of 6 months, a period which is of average length for the studies presented.

2.7 Division by Gender

In Portugal gender differences were a specific question. It was found that there is no significant difference between genders (Ferreira et al., 2008).

None of the remaining 11 studies presented posited the relationship with gender as a criterion. However, in some of them it was included in the findings after the results had been collected.

In Louisiana it was observed that chess only had a positive influence on girls (Smith et al. 1997). Similarly, in Denmark while gender was not a key question, it

was found that boys benefitted slightly more than girls, although the sample was deemed insufficient to substantiate the result. (Gumede et al., 2015). In Turkey no significant differences between genders were noted (Sigirtmac, 2011).

Summary: no study focused on possible differences between genders. Even those which do refer to the topic show divergent results, and consequently this must be regarded as a gap in the research.

2.8 Division by Race, Whether Indigenous or Immigrant and Class Discrimination

The study in Louisiana in 1997 tried to investigate analytics method of perception of 11 Afro-American students (Smith et al. 1997). While it was not one of its research objectives, in Aarhus in Denmark it was found that the results in the experimental group were positive only for Danish students in contrast to immigrants (Gumede et al. 2015). In Turkey the study took place at three private and two public kindergartens whose students were from high socioeconomic classes (Sigirtmac, 2011).

Summary: no study focused on possible differences between indigenous and immigrant students.

In the vast majority of modern societies, a wide range of cultural groups live side by side. Multiculturalism is a necessary feature of modern societies. The transition of modern societies into multicultural ones increases the necessity to investigate this parameter (Levy & Weiss, 2002; Alba, Schmidt & Wasmer, 2003; Alba & Nee, 2003; Koenig, 2005; Markovits, Levy, Pensky & Torpey, 2005; Huysmans, 2006; Wojciechowski, Juchacz, Cern, 2013).

2.9 Evaluatory Tools

Researchers have used a wide range of tools, different for each study, with the aim of documenting their findings. These tools will be referred to briefly, as their further analysis is not judged to be the goal of this review.

i. Group Embedded Figures Test (GEFT)
ii. Raven's Progressive Matrices, Key Math Diagnostic Arithmetic Test, Computerized version of Tower of London Test, The Continuous Performance Test, The Stroop Test

iii. The Korean Basic Skills Test, Raven's Progressive Matrices Test (RPM), SPM & The Test of Nonverbal Intelligence – Third Edition, TONI-3, Chess Quiz, Chess Skill Rating
iv. Analytic Scoring Scale, Cronbach's Alpha and SPSS
v. Kernel density estimate
vi. Artihmetic TEST based among others on Kleber et.al. & Bourdon & Mann–Whitney U test (as referred to in Scholz et.al. 2008)
vii. Math TAKS
viii. PISA (Both studies in Italy)
ix. Wilcoxen
x. Mathematics test designed by the researchers and the Danish book Chess and Mathematics

Summary: the range of statistical tools used does not permit more than the individual presentation of the results of the studies; this is not considered desirable in the context of the current presentation.

2.10 Research Findings

In the majority of studies the findings in relation to the research questions were established after the application of diagnostic tests before and after chess was taught.

The study carried out in Denmark concluded that the positive results observed in the experimental group after learning chess were marked only for native Danish children and not for the children of immigrants (Gumede et.al. 2015). In Iran the difference in favour of the experimental group was clear (Khosrorad et al., 2014). The only study which did not find improvement in the experimental group was that carried out in Seoul. Among the probable caused referred to are the short duration of the programme and the need for further chess improvement (Hong et al., 2003).

In Portugal, where three questions were posited, it was found that the student chessplayers performed better at mathematical and geometric motifs, whereupon it was proposed that chess should be introduced into the school curriculum (Ferreira et al., 2008). In Northern Italy, the results were compatible with the hypotheses. The students in the experimental group had better results than those in the control group (Sala et al., 2015). Similar results were found in Saxony, where the study took place

with children with learning difficulties (Scholz et al., 2008). In Louisiana, it was noted that girls had better results than boys (Smith et al. 1997). The results of the study carried out in Agrigento in Italy may be regarded as quite problematic in terms of their wider relevance owing to the small number (10) of students in the experimental group (D'Eredità et al., 2011).

In Texas it was found that the clear influence of chess on students' mathematical abilities was not combined with analogous results concerning specific measures of mathematical skills such as geometry, sets and so on (Barrett et al., 2011). The study in Turkey focused primarily on spatial concepts since it involved kindergarten pupils and concluded that chess has a clear positive effect on the students (Sigirtmac, 2011). The study carried out on blind students in Turkey concluded that after a sufficient period of time during which the students in the experimental group were able to make progress in chess, there was a clear improvement in their performance in contrast with the control group (Aydin, 2015). Trinchero et al., (2016) claim that only those students in the experimental group who were taught by chess players improved their mathematical performance, in contrast to those taught chess by teachers.

Table 4

Cumulative research table

Writer	Publication Journal	Place	Measuring Tools	YEAR / Publication-Helding	Ages / Class	Students / Experimental - Control	Hours - Duration	Special Needs
Roberto Trinchero, και Giovanni Sala	Eurasia Journal of Mathematics, Science & Technology Education	Italy	OCDE-Pisa	2016/2013-2014	3-5 Grade	931 (2+1)	15 hours / 6months	

Kamilla Gumede & Michael Rosholm	Aarhus University and IZA	Aarhus Denmark	TEST mathematics designed by researchers and the Danish book Chess and Mathematics	2015-2013	1-3 Grade	482 (323+159)	1hour /week 9monts/42lessons	
Giovanni Sala Alessandra Gorini και Gabriella Pravettoni	SAGE OPEN	Italy	OCDE-Pisa -SAM (Scacchi e Apprendimento della Matematica & CAT	2015	8-11 years old	560 - 309 (169+140) και and 251 (116+135)	1-2 hours/week – Total 10/15 hours / 3 months	
Mensure Aydin	Academic Journals	Turkey	Wilcoxen	2015	Secondary school	26 (12+14)	4 hours / week – 12 weeks	Blind Child
Razieh Khosrorad, Sakineh Soltani Kouhbanani & Abolfazl Rahmani Sani	International Journal of Educational Investigations	Tehran-Iran	Stroop Test, Continuous Performance test, the computerized version of Tower of London	2014	9-12 years old	20 (10+10)	1hour/2 times in a week / 1 year	Weak in Mathematics
Ayperi Dikici Sigirtmac	Early Child Development and Care	Turkey	Test Mann–Whitney U test	2012/2011	5-6 years old	103 (50+50)		

Giuliano D'Eredità & Mario Ferro	Quaderni di Ricerca in Didattica Mathematics	Agrigento Sicily Italy	PISA	2011/2008-2010	11 years old	45 (10+35)	30 hours	
David C. Barrett Wade & W. Fish	INTERNATIONAL JOURNAL OF SPECIAL EDUCATION	Texas USA	Math TAKS	2011/2008-2009	6-8 grade	31 (15+16)	1 hour / week 12 lessons/ 30 weeks / 3 months	Learning difficulties
Dores Ferreira και Pedro Palhares	The Mathematics Enthusiast (TMME)	Portugal	Analytic Scoring Scale, Cronbach's Alpha and SPSS	2008	3-6 grade	437 (-)		
Markus Scholz, Harald Niesch, Olaf Steffen, Baerbel Ernst, Loeffler, Markus Evelin Witruk & Hans Schwarz,	INTERNATIONAL JOURNAL OF SPECIAL EDUCATION	Saxony Germany	Αριθμητικά TEST based inter alia on Kleber et al. (1999) & Bourdon (1885)	2008	10 years old	53 (31+22)	1 hour/ week / 1 year	Low IQ
Saahoon Hong & William M. Bart	INTERNATIONAL JOURNAL OF SPECIAL EDUCATION	Seoul - Korea	Raven's Progressive Matrices Test (RPM) & Test of Nonverbal Intelligence TONI-3	2007	8-12 years old	38 (18+20)	1.5 hours / 12 lessons / 3 months	Weak in Mathematics

Smith, James και Sullivan, Monty	EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)	Louisiana USA	Group Embedded Figures Test (GEFT)	1997/1997	16-17	11 (-)	50 hours / 2 months

Chapter 3: Conclusions - Proposals

3.1 Summary of Results

From the large number of studies listed, it can be noted that their results converge, independently of whether the researchers used control groups or other scientific tools. With only two exceptions, all of the studies confirm the initial hypotheses to a greater or lesser extent, irrespective of sample size, age, or when the study was carried out. A significant feature is the variety in terms of both age and sample size, while positive results were found both in classical schools and in those for students with learning difficulties. The overwhelming conclusion to be drawn is that chess not only can but must constitute an educational tool aimed at helping students in multiple ways, as is already the case in practice in a number of countries and has recently started in Greece.

3.2 Conclusions

The theoretical approach to the topic frames sufficiently the need for chess to be used as an educational tool with the aim of obtaining the greatest possible benefit for students. Without going into depth, it demonstrates that chess can be beneficial to students at every level in mathematics and other fields, as is confirmed by the references to studies already carried out. Degroot (1978) notes that there are two main benefits for children who learn chess: i) they learn to lose and that to improve they need to work, and ii) they experience academic, behavioral and social improvement, with parallel increase in their IQ.

It is clear that the present study is by no means exhaustive, and there are further areas which require investigation. In the present study sporadic references were found concerning methodologies and the bibliographies employed, but the approach, which is significant both generally and in terms of age, was omitted. Furthermore, little reference was made concerning the previous knowledge which some students are likely to have had or to the analytical weekly programme. Another omission regarded as significant concerns the interdisciplinary approach to learning with the help of chess, while it would also be useful to have quantitative and qualitative measurements, which only some of the studies have reported. Another

point worth noting is that none of the studies refer to students' difficulty in approaching the subject, given that chess is a difficult and sedentary game. Indeed, when chess comes to the child (chess at school) rather than the child going to chess (chess at clubs), the difficulties are increased and the teachers' pedagogical goal is, and must be, for the child to love chess in order to acquire the maximum benefits from this educational tool.

3.3 Proposals for Future Studies

From the findings of the 12 studies it can be seen that there are various fields which have been researched only partially or not at all, and which the research needs to be widened to include. As catalysts, we propose that the following be studied:

i. Students from different socioeconomic areas
ii. Indigenous and immigrant students
iii. Differences between boys and girls
iv. Differences according to the method of teaching chess
v. The influence of chess on improving students' performance in geometry
vi. Long-term studies with duration of more than one year

It is considered to be significant, before beginning any research, to pay attention to the probable degree of previous chess knowledge and the degree of acceptance of the game on the part of both the students and their parents.

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