CHESS IN SCHOOL CAN IMPROVE MATH ABILITY? DIFFERENCES BETWEEN INSTRUCTOR TRAINING AND TEACHER TRAINING FROM AN EXPERIMENT IN ITALIAN PRIMARY SCHOOLS.

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Abstract

The practice of chess in school can improve mathematical ability of children? Chess training performed by a chess instructor is different from chess training performed by classroom teacher? The research presented in this paper shows that a chess intervention with in-presence lessons managed by a chess instructor, and supported by additional online training, can improve significantly the scores of a group of children on the Oecd-Pisa Mathematics Scale. This improvement is much smaller if chess training is managed by classroom teacher. The research show also that the score gain is greater in subgroups that have attended more hours of chess in-presence lessons and have achieved an higher level in online training. In according to others Italian (*Chess in School* 2005-2013, *Sam - Chess and Math Learning* 2011) and international studies, these results indicates that chess training can be a valuable learning aid that supports acquisition of mathematical abilities, but requires the adoption of specific strategies devoted to development of skills and habits of mind. Research has been conducted on a randomized sample of 1057 children aged from 7 to 11, attending primary schools in several provinces of Italy.

Keywords: Chess in school, Chess training, Cognitive enhancement, Increasing mathematics abilities, Chess training by classroom teachers.

1. Introduction

Several researches put in evidence possible relations between attainment to chess training programs and cognitive abilities of pupils, related to perceptual grouping, information management, attention, various memory functions, logical thinking and problem solving (Bilalić, McLeod, Gobet, 2009; Gobet and Campitelli, 2006; Gobet and Waters, 2003; Saariluoma, 2001). In particular, many studies have tried to demonstrate relationship between playing chess and mathematical ability (see for example Frank, 1978; Christiaen, 1976;

Tudela, 1984; Ferguson, 1986 and 1995; Horgan, 1987; Ho, 2006; Hong & Bart, 2007; Scholtz et al. 2008; Ho, Buky 2008; Barrett & Fish, 2011). According to these studies, systematically playing chess is linked to several abilities that are important in mathematical problem solving, such as the maintenance of a high level of attention and concentration on the task, the focus on details, the perseverance in achieving objectives, the recognition of strategic information from situations and its use in planning strategies, the critical reflection on own actions and the prediction of the course of events.

Nevertheless, these findings have also shown that the causal direction of the relationship is uncertain (Gobet and Campitelli, 2002). There are three possible scenarios to support the empirical evidence collected: a) the game of chess actually improves people's intellectual abilities, b) those with better mental abilities play better chess, achieve better results and thus tend to play more; c) there are intervening factors, such as motivation towards the task, the ability to consider several alternatives and decide which is the best in a limited period of time, which mediate both the expression of intellectual abilities and the ability in the game of chess.

Regarding this debate, several experimental Italian studies (see Trinchero, 2012, 2013; Argentin, Romano, Martini, 2012) have confirmed these hypotheses. The improvement of mathematical abilities has proved to be linked to chess training in primary school children, but only under precise condition: a) a chess training of almost 30 hours per year; b) a chess teaching approach able to develop specific skills and *habits of mind* (see Costa, Kallick, 2009) in pupils: self-reflection about their strategies and consequence of their actions, the ability to analyze situations and problems, the ability to grasp the important elements and remain focused on completing the solution process. Studies have demonstrated that playing chess can be a fun and engaging experience to develop these habits and abilities.

If the teaching approach of chess instructors is so important, the difficulty in diffusing a "good" chess practice in schools, at least in Italy, is the lack of skilled instructors. It is difficult to find a sufficient number of instructors with the necessary training to meet the request of chess training in primary schools. The present study investigates the possibility of using classroom teachers to carry out basic chess training in schools, and the differences, in terms of chess and math skill increase, between the training provided by chess instructors and the training provided by classroom teachers, by applying the same teaching protocol in both groups. Teachers and chess instructors were trained through the online course (CAT, Computer Assisted Training –Victor Cat's Chess House), by a course of 5 in-presence hours, supported via Skype for the entire duration of the experimentation and a reference manual was provided to them. The schools received chess sets and demo boards for free.Chess training, provided by the chess instructors and the teachers of the schools involved, was a mix of training in presence and CAT. The children involved were aged from 7 to 11 years. Mathematical ability was assessed by means of 7 items taken from the Oecd-Pisa inquiry (Oecd, 2009), selected from faceable items for eight years old and older children. The experiment was conducted from October 2013 to May 2014.

2. Method

2.1. Participants

The target group of our investigation was composed by 1057 children aged from 7 to 11, attending primary schools in several provinces of Italy (see details in Table 2, Table 3 and Table 4). The sample was randomly divided into three main groups, showed in Table 1, and several subgroups according to different age of the children, school frequented, duration of the in-presence training, year of the chess training (some groups frequented a multi-year chess training program, as shown in Table 2, Table 3 and Table 4).

Group	*N.*	*Activities*		
G1 (Experimental; school teacher)	221	Pre-test	Blended chess training with school teacher (in presence + CAT)	Post-test
G2 (Experimental; chess instructor)	402	Pre-test	Blended chess training with chess instructor (in presence + CAT)	Post-test
G3 (Control)	434	Pre-test	Ordinary school activities	Post-test

TABLE 1. *The experimental design*.

Details of the participants are showed in Tables 2, 3, 4.

G1 (Experimental; chess training with school teacher)

Subgroup	*N.*	*School*	*N. Classes*	*Chess training*
G1c3-10-1	24	Carducci 3D (Pavia)	1 (grade 3)	10 hours in presence (first year of training) + CAT
G1c4-24-1	20	Colombo 4A (Cremona)	1 (grade 4)	24 hours in presence (first year of training) + CAT
G1m3-6-1	21	Manzoni 3B (Cremona)	1 (grade 3)	6 hours in presence (first year of training) + CAT
G1m4-10-1	21	Manzoni 4B (Cremona)	1 (grade 4)	10 hours in presence (first year of training) + CAT
G1m3-4-10-1	35	Mazzano 3B (Mazzano); Mazzano 3A (Ciliverghe)	2 (grade 3)	10 hours in presence (first year of training) + CAT
G1m3-30-1	22	Montebolone 3A (Pavia)	1 (grade 3)	30 hours in presence, 2 hours per week (first year of training) + CAT
G1m4-20-1	19	Montebolone 4A (Pavia)	1 (grade 4)	20 hours in presence, 2 hours per week (first year of training) + CAT
G1p3-12-1	14	Persico 3A	1 (grade 3)	12 hours in presence, (first year of training) + CAT
G1s3-20-1	11	Schilpario 3B (Schilpario)	1 (grade 3)	20 hours in presence, 3 hours per week (first year of training) + CAT
G1s4-20-1	17	Schilpario 4B (Schilpario)	1 (grade 4)	20 hours in presence, 3 hours per week (first year of training) + CAT
G1s5-17-4	17	Stradivari 5B (Cremona)	1 (grade 5)	17 hours in presence (fourth year of training) + CAT

TABLE 2. *Details of the participants (G1)*

G2 (Experimental; chess training with chess instructor)

Subgroup	*N.*	*School*	*N. Classes*	*Chess training*
G2a3-14-1	17	Alberico 3A (Bergamo)	1 (grade 3)	14 hours in presence, (first year of training) + CAT
G2a4-14-2	23	Alberico 4A (Bergamo)	1 (grade 4)	14 hours in presence, (second year of training) + CAT
G2a2-25-1	63	Andria 2ABD (Andria)	3 (grade 2)	25 hours in presence, (first year of training) + CAT
G2an3-22-1	20	Andria 3F (Andria)	1 (grade 3)	22 hours in presence, (first year of training) + CAT
G2br4-13-1	32	Bambino Rodari 4A (Bergamo)	2 (grade 4)	13 hours in presence, (first year of training) + CAT

G2c3-14-1	36	Capitanio 3BC (Bergamo)	2 (grade 3)	14 hours in presence, 1,5 hours per week (first year of training) + CAT
G2c4-14-1	41	Capitanio 4BC (Bergamo)	2 (grade 4)	14 hours in presence, 1,5 hours per week (first year of training) + CAT
G2c5-10-3	14	Cocconato 5A (Cocconato)	1 (grade 5)	10 hours in presence, (third year of training) + CAT
G2d3-15-1	36	Diaz 3BC (Bergamo)	2 (grade 3)	15 hours in presence, (first year of training) + CAT
G2d4-15-1	15	Diaz 4A (Bergamo)	1 (grade 4)	15 hours in presence, (first year of training) + CAT
G2g3-10-1	21	Ghisleri 3A (Bergamo)	1 (grade 3)	10 hours in presence, (first year of training) + CAT
G2g4-10-2	21	Ghisleri 4B (Bergamo)	1 (grade 4)	10 hours in presence, (second year of training) + CAT
G2r5-15-2	27	Rodari 5A (Bergamo)	1 (grade 5)	15 hours in presence, (second year of training) + CAT
G2u3-15-1	8	Ugovizza 3A (Ugovizza)	1 (grade 3)	15 hours in presence, (first year of training) + CAT
G2uv4-15-1	28	Ugovizza+ Villafranca 4A (Ugovizza+ Villafranca)	2 (grade 4)	15 hours in presence, (first year of training) + CAT

TABLE 3. *Details of the participants (G2)*

G3 (Control)

Subgroup	*N.*	*School*	*N. Classes*
G3a3	18	Alberico da Rosciate 3B (Bergamo)	1 (grade 3)
G3a4	15	Alberico da Rosciate 4B (Bergamo)	1 (grade 4)
G3an4	20	Andria 4D (Andria)	1 (grade 4)
G3b6	16	Bambino 6A (Bergamo)	1 (grade 6)
G3c3	18	Capitanio 3A (Bergamo)	1 (grade 3)
G3c4	18	Capitanio 4A (Bergamo)	1 (grade 4)
G3ca3	26	Carducci 3E (Pavia)	1 (grade 3)
G3co5	14	Cocconato 5B (Cocconato)	1 (grade 5)
G3co4	18	Colombo 4B (Cremona)	1 (grade 4)
G3d3	19	De Amicis 3B (Pavia)	1 (grade 3)
G3d4	21	De Amicis 4A (Pavia)	1 (grade 4)
G3di3	16	Diaz 3A (Bergamo)	1 (grade 3)
G3di4	20	Diaz 4B (Bergamo)	1 (grade 4)
G3g3	21	Ghisleri 3B (Bergamo)	1 (grade 3)
G3g4	18	Ghisleri 4A (Bergamo)	1 (grade 4)
G3m3	17	Manzoni 3A (Cremona)	1 (grade 3)
G3m4	18	Manzoni 4A (Cremona)	1 (grade 4)
G3ma3	12	Mazzano 3A (Mazzano)	1 (grade 3)
G3p3	14	Persico 3B (Dosimo)	1 (grade 3)
G3r3	18	Rodari 3A (Bergamo)	1 (grade 3)
G3r4	17	Rodari 4B (Bergamo)	1 (grade 4)
G3s5	11	Schilpario 5B (Schilpario)	1 (grade 5)
G3st5	21	Stradivari 5A (Cremona)	1 (grade 5)
G3u5	10	Ugovizza 5A (Ugovizza)	1 (grade 5)
G3v4	20	Villafranca 4B (Villafranca)	1 (grade 4)

TABLE 4. *Details of the participants (G3)*

Participants were *randomly selected*. We constructed pairs of homogenous classes and then selected, by a random number generator, class for the experimental group (G1 and G2), and one class for the control group. Another randomization generated G1 and G2. Some classes (18) were dropped from the three groups (G1, G2, G3) for problems of suspect cheating in pre-test and post-test. 8 classes left the experiment before post-test.

2.2. Study design

The study duration was one school year (from October 2013, to May 2014). The classes in experimental groups (G1, G2) received chess lessons in school hours. At the same time of in-presence course, the pupils were invited to do (mainly at home, but in some cases also in the computer classroom at school) a computer-assisted training (CAT) on the Web (*www.europechesspromotion.org* and *www.scacchiedu.it*) that provided 12 levels of training, developed by the Piedmont Regional Fsi Committee and Alfiere Bianco Amateur Sports

Company, in collaboration with the Italian Council of Research (Cnr) of Rome. The chess contents of the CAT were the same of in-presence lessons (CAT activities are a reinforce of in-presence lessons), and the activities were subdivided in Demonstration (pupils see how to do a move), Practice (pupils try to find the correct move and receive a feedback) and Learning Test (pupils solve problems that implicate the knowledge of that move and receive a feedback). The classes in Group 3 (control) received the planned regular lessons, and had not access to chess CAT.

Table 5 shows the Oecd-Pisa items used in the study. Item were selected to be faceable from children of grade 3, and of different levels of difficulty, as estimated by Oecd-Pisa.

Item	*Oecd-Pisa item code*	*Math abilities involved*	*Estimated difficulty (from Oecd-Pisa)*	*Score*	*Analogy with chess ability*
10	M145Q01	Calculate the number of points on the opposite face of showed dice	478 (Level 2)	0/1	Calculate material advantage
11	M806Q01	Extrapolate a rule from given patterns and complete the sequence	484 (Level 3)	0/1	Extrapolate checkmate rule from chess situation
12	M510Q01T	Calculate the number of possible combination for pizza ingredients	559 (Level 4)	0/1	Explore the possible combination of moves to checkmate
13	M520Q1A	Calculate the minimum price of the self-assembled skateboard	496 (Level 3)	0/1	Calculate material advantage
14	M159Q05	Recognize the shape of the track on the basis of the speed graph of a racing car	655 (Level 5)	0/1	Infer fact from a rule (e.g. possible moves to checkmate)
15	R040Q02	Establish the profundity of a lake integrating the information derived from the text and from the graphics	478 (Level 2)	0/1	Find relevant information on a chessboard
16	M266Q01	Estimate the perimeter of fence shapes, finding analogies in geometric figures	687 (Level 6)	0/1	Find analogies in chessboard situations

TABLE 5. *Oecd-Pisa items used in the study*

Table 6 shows the chess items used in the study. Item were selected to inquiry several chess abilities that were object of the course.

Item	*Chess ability*	*Score*
19	Explain checkmate situation	0/1
20	Identify checkmate situation	-3/+2
21	Establish if a move is allowed for a piece	-2/+2
22	Identify castling situation	0/1
23	Calculate material advantage	0/1
24	Identify common elements in three chess situations	-3/+3
25	Identify pawn promotion	0/1
26	Identify the possibility of stalemate	0/1
27	Identify checkmate situation	0/1
28	Identify checkmate-in-one-turn situation	0/1
29	Reconstruct sequence of chessboard events	0/1
30	Identify common elements in three chess situations	-3/+3

TABLE 6. *Items relative to chess abilities*

Group 1 (experimental; chess training with school teacher), Group 2 (experimental; chess training with chess instructor) and Group 3 (control) performed a pre-test a week before the chess course and a post-test one or two week after the conclusion of the in-presence course. Both tests were administered by computer. The CAT was used by children in the same period as they had in-presence lessons, and it was a reinforcement of these latter and an opportunity to put into practice the concepts learnt in class.

Pre-test and post-test used the same items in order to guarantee comparability of the results and to exclude differences in items difficulty. This could lead to a noticeable *testing effect* (see Campbell, Stanley 1963; Shadish, Cook, Campbell 2002) which was supposed to be identical in experimental and in control groups, since they were randomly selected.

Chess lessons were based on a method especially designed for 7-11 years old children (applied wholly or in part, depending on the number of hours of in-presence lesson done or level of the class), which were already used in the studies *Can chess training improve Pisa scores in mathematics?* (Trinchero, 2013) and *Sam - Chess and math learning* (Argentin, Romano, Martini, 2012). Contents of the lessons were: the chessboard, the coordinates, the pieces and the rules of movement, the catch and the defense of themselves, the checkmate, the mini-games (e. g. flags, invents a checkmate, King and two Rookies vs. King), the games, the relative value of the pieces and the material advantage, the castling move, the develop of the pieces, the stalemate. Part of teaching materials are available at the address *www.europechesspromotion.org*.

In each lesson, the trainer explained chess rules with a wall-chessboard for a maximum of 15 minutes, then the pupils played mini-games in pairs or games with mates and trainer to put in practice the theory explained. The lessons also included several exercises (about 15 minutes): the pupils had to evaluate which piece was threatened and how to defend it, which piece was threatened and which piece could capture it, which was the most favorable exchange, which was the better piece to capture in a chess situation. Pupils received an immediate feedback and an evaluation in chess ability.

2.3. Statistics

The data were analyzed using a series of univariate and repeated measures ANOVAs, and a series of linear regression analyses. Initial (pre-test) and final (post-test) scores in mathematics and chess were calculated for each pupil. Then the gain for each pupil was calculated, in terms of difference between post-test score and pre-test score. We compared the gain of the experimental groups (and subgroups) and the gain of the control group with univariate and repeated measures ANOVA (Analysis of variance) and linear regression analyses. Calculations were performed using the statistical software package IBM SPSS ver. 20.

3. Results

3.1. Process of the study

Feedbacks from pupils and from teachers were positive. All the experimental classes showed a keen interest in learning chess basics and in using chess CAT software. None of the pupils used the CAT before this training. Table 7 and Table 8 show the mean of achieved level (the maximum was 12) for each subgroup.

			Achieved level in online game	
Subgroup	*Players*	*% on the subgroup*	*Mean*	*St. dev.*
G1m4-20-1	13	68	4.54	3.69
G1m3-6-1	15	71	5.40	3.96
G1p3-12-1	14	100	6.29	3.99
G1m3-30-1	17	77	7.00	4.11
G1c3-10-1	24	100	8.46	3.27
G1m4-10-1	21	100	9.19	2.52
G1m3-6-1	35	100	10.91	2.29
G1c4-24-1	20	100	11.35	0.49
G1s4-20-1	17	100	11.35	0.61
G1s3-20-1	11	100	11.64	0.51
G1s5-17-4	17	100	11.71	0.77

TABLE 5. *Sw usage for G1 and achieved level in online game*

			Achieved level in online game	
Subgroup	*Players*	*% on the subgroup*	*Mean*	*St. dev.*
G2a2-25-1	45	71	5.44	4.01
G2an3-22-1	14	70	5.57	4.18
G2c3-14-1	35	97	6.00	2.99
G2d4-15-1	15	10	7.73	4.22
G2a3-14-1	14	82	7.93	3.29
G2a4-14-2	21	91	8.00	3.76
G2r5-15-2	26	96	8.12	4.29
G2d3-15-1	35	97	8.51	3.43
G2g3-10-1	21	100	9.43	2.34
G2br4-13-1	32	100	9.66	2.98
G2c4-14-1	39	95	9.85	2.71
G2g4-10-2	21	100	10.05	2.77
G2c5-10-3	11	79	10.91	2.47
G2uv4-15-1	28	100	11.50	2.08
G2u3-15-1	8	100	12.00	0.00

TABLE 7. *Sw usage for G2 and achieved level in online game*

3.2. Results for mathematical ability

Univariate ANOVA showed that the three groups significantly differed in terms of age ($F(2, 1054) = 16.354$; $p < 0.001$) and in terms of pre-test math scores ($F(2, 1054) = 5.666$; $p < 0.01$). The t-test between G1 and G2 showed that the two groups did not differ in terms of amount of hours of in-presence lessons ($t(621) = 0.414$; $p = 0.54$. Descriptive statistics are summarized in Table 9.

	Age		*Hours in-presence*		*Pre-test math score*	
Group	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.

G1	8.46	0.67	16.05	6.82	1.52	1.15
G2	8.36	0.91	15.77	4.66	1.38	1.14
G3	8.69	0.87	/	/	1.65	1.25

TABLE 9. *Descriptive statistics for each group*

Univariate ANOVA analysis (math gain as dependent variable, group as fixed factor, and age as covariate) showed a significant effect of group ($F(2, 1053) = 10.019$; $p < 0.001$) on math gain. The pairwise comparisons showed that Group 2 was significantly superior than the other two groups ($p < 0.001$ compared to Group 3; $p < 0.05$ compared to Group 1) in terms of math gain, whereas Group 1 was not significantly better than Group 3 ($p = 1.00$).

The 3x2 repeated measures ANOVA (Group: Experimental (1) vs. Experimental (2) vs. Control (3); Condition: Pre vs. Post math scores; with age as covariate) analysis showed a significant effect of interaction between group and condition ($F(2, 1053) = 10.019$; $p < 0.001$), but no significant main effects of condition ($F(1, 1053) = 0.306$; $p = 0.58$) and group ($F(2, 1053) = 0.263$; $p = 0.77$) on mathematical abilities.

Then, a univariate ANOVA analysis showed a main effect of group ($F(2, 1053) = 10.019$; $p < 0.001$) on math gain. The results are summarized in Table 10.

	Pre-test score		*Post-test score*		*Gain*
Group	Mean	St. dev.	Mean	St. dev.	
G1	1.54	1.15	1.74	1.04	0.21
G2	1.38	1.14	1.94	1.32	0.56
G3	1.65	1.25	1.78	1.29	0.13

TABLE 10. *Descriptive statistics of math scores in the three groups.*

The pairwise comparisons showed that Group 2 was significantly superior than the other two groups ($p < 0.001$ compared to Group 3; $p = 0.01$ compared to Group 1) in terms of math gain, whereas Group 1 was not significantly better than Group 3 ($p = 1.00$).

Finally, a series of repeated measured ANOVA analyses was performed, in order to evaluate the significance of the improvement at math in every subgroup. The results are summarized Table 11, Table 12 and Table 13. The three tables show the mean and standard deviation for the pre-test and post-test scores and the score gain relevant to whole experimental group, experimental subgroups, and control group. The subgroups are ordered by mean of the score gain. Gain significance (sixth column) refers to ANOVA between gain of the control group and gain of each single experimental subgroup.

	Pre-test score		*Post-test score*		*Gain*	*Sign.*
Subgroup	*Mean*	*St. dev.*	*Mean*	*St. dev.*		
G1m3-4-10-1	1.86	1.38	1.43	0.98	-0.43	0.105
G1s3-20-1	1.55	1.21	1.27	0.65	-0.28	0.341
G1m4-20-1	1.53	1.02	1.47	0.84	-0.06	0.848
G1s4-20-1	1.65	1.06	1.76	1.03	0.11	0.750
G1s5-17-4	2.24	0.97	2.41	1.37	0.17	0.548
G1m3-6-1	1.43	1.21	1.62	0.87	0.19	0.446
Whole G1	*1.54*	*1.15*	*1.74*	*1.04*	*0.21*	-
G1c3-10-1	1.38	0.82	1.75	1.29	0.37	0.142
G1m4-10-1	1.33	1.32	1.76	0.94	0.43	0.143
G1m3-30-1	1.23	1.11	1.86	0.64	0.63	0.031
G1p3-12-1	0.93	0.83	1.57	1.09	0.64	0.082
G1c4-24-1	1.45	1.15	2.25	1.12	0.8	0.008

TABLE 11. *Score gain in mathematics ability (G1 Subgroups).*

	Pre-test score		*Post-test score*		*Gain*	*Sign.*
Subgroup	*Mean*	*St. dev.*	*Mean*	*St. dev.*		
G2g4-10-2	2.05	1.07	1.52	1.25	-0.53	0.045
G2d3-15-1	1.39	1.05	1.42	1.00	0.03	0.900
G2a3-14-1	1.12	0.93	1.24	1.09	0.12	0.707
G2u3-15-1	1.25	1.28	1.50	1.31	0.25	0.732
G2g3-10-1	1.43	0.98	1.71	0.90	0.28	0.284
G2c5-10-3	1.71	1.49	2.14	1.56	0.43	0.165
G2a4-14-2	2.00	1.38	2.48	1.28	0.48	0.156
G2uv4-15-1	1.00	1.09	1.54	1.04	0.54	0.011
Whole G2	*1.38*	*1.14*	*1.94*	*1.32*	*0.56*	-
G2br4-13-1	1.34	1.10	1.97	1.03	0.63	0.017
G2c3-14-1	1.00	0.89	1.67	1.15	0.67	0.006
G2d4-15-1	2.13	1.30	2.87	1.55	0.74	0.022
G2c4-14-1	1.54	1.10	2.34	1.15	0.8	0.000
G2a2-25-1	0.95	0.99	1.76	1.57	0.81	0.000
G2r5-15-2	1.96	1.22	2.81	1.27	0.85	0.018
G2an3-22-1	0.85	0.59	2.35	1.46	1.5	0.000

TABLE 12. *Score gain in mathematics ability (G2 Subgroups).*

	Pre-test score		*Post-test score*		*Gain*	*Sign.*
Subgroup	*Mean*	*St. dev.*	*Mean*	*St. dev.*		
G3an4	2.60	1.67	1.75	1.07	-0.85	0.111
G3u5	2.00	1.56	1.40	1.17	-0.6	0.239
G3g3	1.71	1.15	1.19	1.17	-0.52	0.157
G3b6	2.44	1.03	2.06	1.34	-0.38	0.138
G3a3	1.39	0.98	1.06	0.54	-0.33	0.269
G3d3	1.05	1.18	0.84	1.12	-0.21	0.480
G3g4	1.67	0.84	1.56	1.29	-0.11	0.767
G3di3	1.00	0.76	0.93	0.70	-0.07	0.774
G3v4	1.40	1.05	1.45	1.00	0.05	0.804
G3c3	1.33	1.46	1.39	0.92	0.06	0.871
G3a4	2.60	1.35	2.67	1.11	0.07	0.872
Whole G3	*1.65*	*1.25*	*1.78*	*1.29*	*0.13*	-
G3r4	1.75	1.13	1.94	1.00	0.19	0.485
G3r3	1.17	1.30	1.39	1.20	0.22	0.562
G3d4	1.95	1.24	2.19	1.40	0.24	0.382
G3s5	2.36	0.81	2.64	0.92	0.28	0.341
G3m3	1.24	0.90	1.53	1.07	0.29	0.369
G3p3	1.00	0.78	1.29	1.27	0.29	0.525
G3st5	2.05	1.12	2.38	1.20	0.33	0.273
G3co5	1.86	1.70	2.29	1.73	0.43	0.321
G3c4	1.39	0.98	1.94	1.43	0.55	0.086
G3co4	1.33	1.03	1.89	1.71	0.56	0.189
G3m4	1.72	1.13	2.28	1.23	0.56	0.096
G3ca3	1.31	1.32	1.88	1.48	0.57	0.049
G3ma3	1.50	1.00	2.08	0.67	0.58	0.171
G3di4	1.90	1.45	2.75	1.37	0.85	0.009

TABLE 13. *Score gain in mathematics ability (G3 Subgroups).*

The groups analyses put in evidence a significant gain for groups: a) trained by a chess instructor; b) that attended more hours of in-presence chess training. The level reached in the CAT seemed to have no significant influence on the gain of groups, even if, for the classroom teacher training, groups that achieved a significant gain were the groups that reached an higher level in the CAT (G1c4-24-1) or group that attended 30 hours of in-presence lessons (G1m3-30-1). These results corroborate the hypothesis that the effect of chess training on math abilities depends on the duration of the training and the teaching approach of the instructor.

With regard to possible intervening variables, there were no significant gender differences in pre-test math scores ($t(1055) = 0.485$; $p = 0.63$), and no significant difference in terms of mean age between boys and girls either ($t(1055) = 1.202$; $p = 0.23$). However, boys proved to be better at post-test math scores than girls (M(m) = 1.91, S. D. = 1.25; M(f) = 1.75, S. D. = 1.25; $F(1, 1055) = 4.441$; $p < 0.05$).

3.3. Results for chess ability

Descriptive statistics of chess abilities are summarized in table 14.

	Pre-test score		*Post-test score*		*Gain*
Group	*Mean*	*St. dev.*	*Mean*	*St. dev.*	
G1	1.52	3.40	6.03	4.54	4.51
G2	2.41	4.30	8.21	4.96	5.80
G3	2.16	3.84	3.18	4.51	1.02

TABLE 14. *Descriptive statistics of chess scores in the three groups.*

The 3x2 repeated measures ANOVA (Group: Experimental (1) vs. Experimental (2) vs. Control (3); Condition: Pre vs. Post; with age as covariate) analysis showed a significant main effect of group ($F(2, 1053) = 83.628$; $p<0.001$) and condition ($F(1, 1053)= 11.402$; $p = 0.001$), and also a significant interaction between the two ($F(2, 1053) = 158.328$; $p < 0.001$) on chess performance. The pairwise comparisons showed that Group 2 performed significantly better than the other two groups ($p < 0.001$), and that Group 1 performed significantly better than Group 3 ($p < 0.001$), as expected.

The results of the Subgroups are summarized in Table 15 (G1 Subgroups) and in Table 16 (G2 Subgroups).

	Pre-test score		*Post-test score*		*Gain*	*Sign.*
Subgroup	*Mean*	*St. dev.*	*Mean*	*St. dev.*		
G1p3-12-1	0.93	2.70	1.57	3.03	0.64	0.487
G1m3-6-1	0.48	2.29	2.71	3.24	2.23	0.007
G1m4-10-1	1.14	2.54	3.71	3.59	2.57	0.001
G1s5-17-4	9.18	3.66	11.76	4.22	2.58	0.001
G1m4-20-1	1.00	3.23	4.58	3.22	3.58	0.000
G1m3-4-10-1	1.03	2.47	5.66	3.44	4.63	0.000
G1m3-30-1	0.36	1.43	5.18	4.45	4.82	0.000
G1s4-20-1	2.06	3.73	7.82	4.84	5.76	0.000
G1c3-10-1	1.08	2.72	7.04	3.48	5.96	0.000
G1s3-20-1	0.91	1.92	7.09	3.94	6.18	0.000
G1c4-24-1	0.00	0.00	9.80	3.52	9.8	0.000

TABLE 15. *Descriptive statistics of chess scores in Group 1.*

	Pretest score		*Posttest score*		*Gain*	*Sign.*
Subgroup	*Mean*	*St. dev.*	*Mean*	*St. dev.*		
G2r5-15-2	10.04	3.88	11.85	3.97	1.81	0.002
G2g4-10-2	5.71	4.47	8.81	5.14	3.1	0.000
G2u3-15-1	1.50	2.39	4.62	3.34	3.12	0.016
G2c5-10-3	8.07	5.57	11.57	3.55	3.5	0.003
G2a3-14-1	1.24	3.13	4.82	4.92	3.58	0.002
G2a4-14-2	7.56	5.02	11.96	4.34	4.4	0.000
G2c3-14-1	0.33	1.53	5.19	3.54	4.86	0.000
G2uv4-15-1	2.61	3.86	7.75	3.80	5.14	0.000
G2a2-25-1	-0.05	0.28	5.70	4.97	5.75	0.000
G2g3-10-1	0.52	1.86	6.62	4.34	6.1	0.000
G2d3-15-1	1.06	2.74	7.94	4.64	6.88	0.000
G2d4-15-1	4.33	5.07	11.87	4.41	7.54	0.000

G2c4-14-1	1.00	2.55	8.98	4.30	7.98	0.000
G2an3-22-1	0.00	0.00	8.50	5.17	8.5	0.000
G2br4-13-1	0.63	1.64	10.44	4.25	9.81	0.000

TABLE 16. *Descriptive statistics of chess scores in Group 2.*

G1c4-24-1 subgroup obtained a significant gain in math and in chess and this corroborate the hypothesis that the two abilities are in some way linked.

Finally, a linear regression analysis (method stepwise) was performed in order to evaluate the weight of every significant predictor of the gain of chess post-test scores compared to chess pre-test scores. The model is shown in Table 17.

Model	*Beta coefficient*	*t*	*Sign.*
Constant	/	-2.634	0.009
Pre-test chess scores	-0.455	-11.268	0.000
CAT level achieved	0.303	7.879	0.000
Hours of chess course	0.167	4.446	0.000
Age	0.150	3.605	0.000

TABLE 17. *Linear regression analysis for chess gain in the two experimental groups.*

With regard to possible intervening variables, there is no significant gender differences in gain for chess scores neither in experimental (ANOVA, sign.=0.396) nor in control group (ANOVA, sign.=0.087).

3.4. Predictors of post-test math scores

Two linear regression analyses (method stepwise) were performed in order to evaluate the weight of every significant predictor of post-test math scores in Group 1 (N = 221) and in Group 2 (N = 399). The two models are shown in table 18.

Model	*Beta coefficient*	*t*	*Sign.*
Group 1			
Constant	/	8.541	0.000
Post-test chess scores	0.250	3.853	0.000
Pre-test math scores	0.222	3.425	0.001
Group 2			
Constant	/	0.514	0.608
Post-test chess scores	0.443	9.754	0.000
Pre-test math scores	0.200	4.378	0.000
Hours of chess course	0.119	2.678	0.008
Constant	/	0.514	0.608

TABLE 18. *Predictors of post-test math scores*

As expected, post-test chess scores proved to be the most important predictor of post-test math scores in both the models. This outcome demonstrated that the ability to play chess was the decisive factor linked to mathematical ability, much more than the hours of in-presence lesson and even than pre-test math scores. Thus, it is reasonable to assume that children are supposed to improve on mathematics only if they actually learn to play chess. Therefore, the mere exposure to chess lessons is not sufficient to allow the transfer of any ability from chess to mathematics domain.

4. Discussion

The aim of our study was to investigate the influence of two different typologies of chess training (chess courses run by chess instructors and by a classroom teacher) on mathematics and chess abilities. In according to previous research (*Chess in School* 2005-2011, *Sam - Chess and Math Learning* 2011, see Trinchero 2012, and *Can chess training improve Pisa scores in mathematics?*, see Trinchero 2013) and to our hypothesis, we found a clear advantage in Group 2, that is the group run by chess instructors, compared to Group 1, that is the group run by school teachers, for the improvement of problem solving ability in mathematics. The advantage is greater in subgroups that attended more hours of in-presence chess lessons and/or achieved a higher level in online chess training.

Further research is necessary in order to explain why the chess training with chess instructor promotes this significant increase. Some possible explanations are presented in Trinchero (2012 and 2013) and refer to the ability of chess instructors to help pupils to develop specific skills and habits of mind (see Costa and Kallick, 2009), such as persisting in a task, managing attention and impulsivity, gathering and using data to make appropriate decisions, thinking in flexible manner, reflecting on own strategies, predicting consequences of their action and taking responsible risks, striving for accuracy, questioning and posing problems, applying past knowledge to new situations, and so on.

It is possible to suppose that chess instructors are much more used to have a teaching approach based on problem solving than are school teachers. The mere knowledge of chess basic rules (as the movement of the pieces) is by far insufficient to train cognitive skill. It is hard to see why knowing that the Queen can move vertically, horizontally and diagonally, for example, should improve children problem solving skills, or any other intellectual skill. Conversely, knowing how to find the shortest path from one square to another one for the Queen (or for any other piece), or knowing whether it is worth to give up a piece for another one, are more demanding tasks for the intellectual skills of the pupil. A pupil playing a chess game moving the pieces correctly (that is, according to the rules), but without any plan or calculation does not use any problem-solving ability. Conversely, it is reasonable to assume that a pupil playing a chess game moving the pieces according to a strategy (albeit ingenuous or shallow for an expert chess player) and paying attention to the dynamic relationships between the pieces is training his/her problem solving ability.

The chess instructor's complete and certain vision, while children are learning the basic rules playing on the chessboard, is able to provide immediate feedback to them. Normally, using this constant and simple approach, an instructor can give a lot of inputs in class, in terms of attention and analysis, during lesson time. The smaller experience in chess that a school teacher normally has, who still needs more time to immediately identify the difficulties in learning, could give, more slowly in lesson time, less feedbacks and inputs at all.

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