DOES PLAYING CHESS IMPROVE MATH LEARNING?

PROMISING (AND INEXPENSIVE) RESULTS FROM ITALY

EDUC 680

PROF. ROBERT BORUCH

GRADUATE SCHOOL OF EDUCATION

UNIVERSITY OF PENNSYLVANIA

BARBARA ROMANO

December 21, 2011

Table of content

ABSTRACT

Background: The existing evidence on the effect of chess on math learning is inconclusive

Aim of research: Explore effectiveness of teaching chess in elementary school, by means of a low budget RCT, sustained by a highly committed research team

Setting: 33 schools, located in three quarter of Italian regions, volunteering to participate in an RCT

Intervention: About 30 hours of chess instruction by certified staff in the course of 3rd grade

Research design Each school participates with at least two 3rd grade classes, one of which is randomly selected to be delayed to 4th grade.

Data collection: A math pre-test and a post-test are administered to all students of the experimental and control classes.

Analysis methods: Simple t-test are performed, then estimates are adjusted with multiple regression and corrected for clustering, and effect sizes are computed. Interactions are extensively explored.

Results: Main finding is that in Italy learning chess in school in 3rd grade increases math achievement by a third of a standard deviation. Interactions are significant for two crucial variables**:** residing in the south and being foreign born. Southern students present an effect size almost twice as large as their northern colleagues (relevant because the south always score much worse in standardized tests). Foreign born students score analogously better than the native born.

Limitations: The study is weak on external validity, due to the volunteer and network-related nature of participation in the program.

Extensions: Important development would be to randomly select schools within which the randomly assign classes, providing incentive for school participation and eventually correcting for non-compliance.

Introduction

The study presented in this paper examines the effects of being taught to play chess in the course of the 3rd grade, specifically the effect on mathematics achievement of pupils attending Italian elementary public schools. The study was severely underfunded but it was made possible by the volunteer work of a small number of researchers committed to rigorous education research. The team included, in addition to the author of this paper, Gianluca Argentin, Alberto Martini and Alessandro Dominici. This project was called SAM (Scacchi e Apprendimento della Matematica—Chess and Math Learning).

The intervention consisted in approximately 30 hours of classroom instruction provided to 3rd graders by instructors certified by the Italian Chess Federation (ICF). The intervention was implemented in over 30 schools located in 14 regions during the 2010/11 school year, under the leadership of the Piemonte Regional branch of the ICF, with the financial support of a grant-making foundation. The funds available for the intervention were about € 30,000 and the budget allocated to the evaluation was less than € 4,000.

The existing evidence on the effectiveness of learning chess

In few countries chess are taught as a constituent element part of the school curricula. This is an old tradition in the Eastern European Countries, but chess are taught as well in some school district in Canada, America and even in Europe. It is not clear whether in these countries this practice is a matter of tradition or chess could really play a role in improving overall school performance, and in particular math achievement.

Undoubtedly playing chess requires strong problem solving abilities and chess players show uncommon memory and concentration abilities (Sweller, Clark, Kirschner, 2006). The heart of the matter is: are these characteristics entirely pre-existing or playing chess contributes to develop them? Common sense suggests that there is a mixture of the two: people with certain characteristics approach chess and chess help them to improve (amplify) these traits. If this is true, chess could be used to help people who usually won't approach chess to improve their problem solving, concentration and memory abilities?

Some educational psychologists object to this possibility. Sweller, Clark, Kirschner (2006) for example relate problem-solving in a particular subject to memories developed in *that* particular subject. They write: "*The superiority of chess masters comes not from having acquired clever, sophisticated, general problem-solving strategies but rather from having stored innumerable configurations and the best moves associated with each in long-term memory.*" So that problem-solving – as memory – would be 'subject specific' and using chess to improve math problem-solving would be a failure: "*minimal instructional guidance in mathematics leads to minimal learning"* (Kirschner, Sweller, & Clark, 2006).

On the other hand some studies claims that chess promotes academic performance through developing visual memory, attention span, spatial reasoning skills, capacity to predict and anticipate consequences, critical thinking, self-confidence, self-respect and problem solving skills (Berkman, 2004; Buki, 2008; Campitelli, 2008, Hong, 2007).

Ferguson (1983) with the American Chess Federation founded the Chess in Schools Program which initially began in New York's Harlem School district. Early in the program, the focus was on improving math skills for adolescents through improved critical thinking and problem solving skills. Remarkably, the ACF reports that chess improves among those taught:

"Ability to use critical thinking (e.g. criteria to drive decision making and evaluate alternatives in testing) improved scores by 17.3% for students regularly engaged in chess classes, compared with only 4.56% for children participating in other forms of enriched activities."

The mathematics curriculum in New Brunswick, Canada, is a text series called "Challenging Mathematics" which uses chess to teach logic from grades 2 to 7. Using this curriculum, the average problem-solving score of pupils in the province increased from 62% to 81%. The Province of Quebec, where the program was first introduced, has the best math marks in Canada.

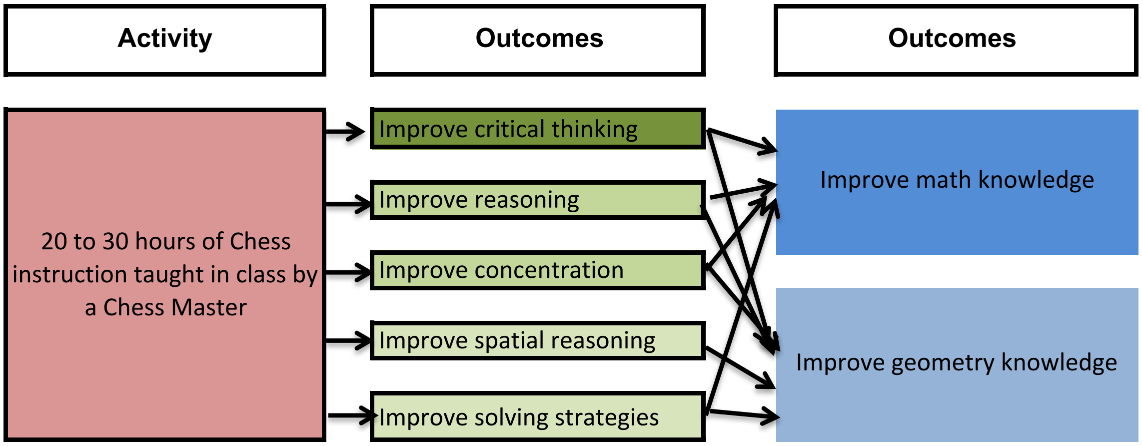
Liptrap (1998) in his study on “Chess and Standard Test Scores” shows that chess improve both math and reading scores for elementary students as it is also suggested by the Marguiles (1998) study “The Effect of Chess on Reading Scores".

Despite all these studies, the evidence produced is not convincing and inconclusive. Some studies rely on too few cases to be defensible, others are focused on students already active in playing chess (Thomson, 2003), for others is not possible to understand from the available understand how the experimental and control group were selected.

The study design

The intervention finds its motivation in the theory presented above, suggesting that problem solving and abilities are not only “subject-specific”, but could be developed in different ways. Namely the intervention is based on the idea that math abilities—such as critical-thinking, solving strategies, reasoning and concentration—could be enhanced by learning chess and not only by solving math problems. The underlying theory of change is represented in the following logic model:

Figure 1. The SAM program Logic Model



The SAM intervention consisted of 20 to 30 hours of chess instruction delivered in the classroom *during regular school hours* by a certified instructor. The actual number of hours of instruction varied depending on the school's availability of resources and on the number of hours that the regular classroom teachers made available for it. We have no evidence of the effect of different hours on the outcomes, as they were not randomly assigned.

Two research questions are the focus of this study: (a) *being taught chess in third grade does improve math achievement*? and (b) *being taught chess in third grade is more effective for some students than for others?*

Recruitment of schools and random assignment of classes

The enrollment of schools in the study was totally voluntary. Actually, no general announcement was made, rather an existing network of schools was alerted of the opportunity. Such network consisted mainly of the schools that in the past years had worked with the Italian Chess Federation. The only condition for a school to be enrolled was to adhere to SAM with at least two 3rd grade classes, one of which was later denied chess instructions in 3rd grade.

We were forced to use this approach because the lack of resources to conduct a systematic nationwide recruitment effort to guarantee external validity. All the schools that accepted the protocol were included in SAM—namely they had to accepted the following condition: *at least one of the 3rd grade classes enrolled was randomly assigned to receive SAM in 4th grade*, while all the others received the treatment in *3rd* grade.

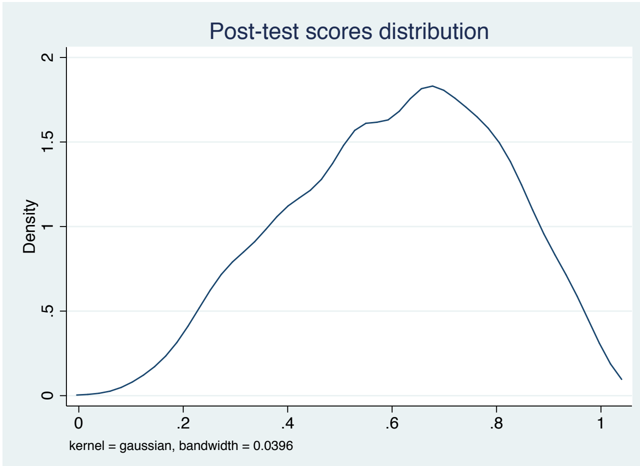
At the conclusion of the recruitment process, there were 123 classrooms in 33 schools, located in 14 out of the 20 Italian regions. Of these 123 classes, 58 were controls and 65 were experimentals.

Outcome measures and data collection

The students were assessed at the beginning and at the end of the end of the 2010/11 school year. The outcome of interested was math achievement. To measure achievement at the pre-test, we used the INVALSI standardized test used in the previous year by the National Institute for Education Evaluation (INVALSI). The INVALSI's is a standardized test administered at the end of year to all Italian 2nd grade students. We considered it an adequate instrument, because at the beginning of the 3rd grade math abilities should be almost the same as at the end of the 2nd grade. Given that all the students in our study took the INVALSI test at the end of School Year 2009/10, we used the 2008/09 INVALSI test to avoid the risk some learning effect. The students that took the pre-test where 1,996 (almost 97% of the eligible ones.)

For the post-test, a brand new test was developed. The constructs measured were the same as in the pre-test, but the difficulty was higher. The distribution of the post-test scores reported in Figure 2 shows that the test, even if a little bit negatively skewed, was able to discriminate and there were no ceiling nor floor effects. Therefore there should be no "instrumentation" threats to internal validity. Both pre and post-test consisted of 28 multiple-choice items. The scores are presented in percentage of correct answers.

Figure 2 – Post-test scores distribution



At baseline test we collected from the student some background information with standardized multiple choice questions: country of birth (Italy or abroad), parent's country of birth (Italy or abroad), sex, attitude toward math, self perceived performance in math as well as ability in chess.

The test had been administered in class through a web platform under a Chess instructor supervision. Because of the tight budget constraint we were not able to afford external and neutral data collectors that would have secured standardization of test administration procedures.

Empirical results

The baseline data collected at the pre-test can be used to gain some understanding of which student characteristics are related to their math achievement, including demographics (sex, immigration status, residence) and well as attitudes, namely the attitude toward math, the self-perception of performance in math, the previous knowledge of chess game. The results are shown in Table 1.

Table 1 – Differences in pre-test scores by student characteristics

Student Characteristics	Mean score on pre test		difference	t-statitsitc
Sex	*Male*	*Female*		
	64.39	63.23	-0.11	1.41
Either parent foreign born	*Yes*	*No*		
	59.71	65.77	-6.48	5.75
Foreign born	*Yes*	*No*		
	56.37	64.86	-8.49	4.74
North-South residence	*North*	*South*		
	64.20	63.33	0.8	1.21
"Do you like math?"	*Yes*	*Not so much/No*		
	65.99	62.33	3.75	4.57
"Do you do well in math?"	*Yes*	*Not so much/No*		
	67.33	62.96	4.36	5.05
"Do you know how to play chess?"	*Well*	*Not so well/No*		
	63.56	63.89	-0.3	0.31

While neither sex nor residence have a significant effect, being foreign born status has a sizeable negative effect that lowers performance on the pre-test by 6 to 8 percentage points. As expected, students who like math or with good self perceived math abilities, perform better on the pre-test. However, they score only about 4 percentage point higher than their classmates.

Testing the equivalence of experimentals and controls

The pre-test scores and the information collected with the baseline questionnaire allow us to check for the equivalence between experimentals and controls. We considered both the demographic characteristics of the student as well as the self-reported measures.

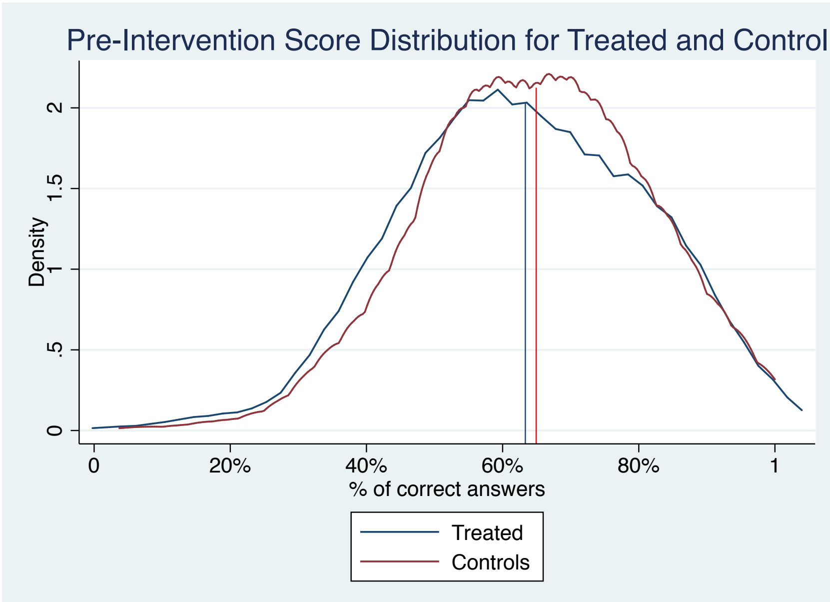
Table 2 – Comparison of baseline characteristics of experimentals and controls

	Percent			
	Experimentals	Controls	Difference	*t-statistic*
Male	53.2	51.4	1.76	*0.78*
Foreign born	5.78	6.46	-1.46	*0.62*
Either parent foreign born	16.6	18.4	-1.74	*1.03*
Lives in the south	43.3	39.3	4.01	*1.91*
"I like math"	57.6	56.5	1.05	*0.46*
"I am good at math"	32.7	34.5	-1.84	*0.86*
"I know how to play chess"	15.8	15.9	-0.07	*0.04*
Total sample	1,071	925		

All the characteristics considered are equally distributed except for the area of residence: in the experimental group the proportion of students from the South is significantly larger. In all national and international math achievement survey students from the South have worst performance than students in the North. Consequently this uneven distribution could lead to an underestimate of the treatment effect. But in the next paragraph we will show that this is not the case in our study.

Experimental and controls have the same distribution on the pre-test. As shown in Figure 2, the distribution of scores is roughly normally shaped (although slightly negatively skewed). There is a significant but small difference between the means: for the experimentals the mean score is 63.06 and for the controls was 64.74, about 1.7 percentage point (2.8%) in favor of the control group, with a t-statistic equal to 2.80. This difference will be corrected in the final analysis by including the pre-test among the explanatory variables in the regression equation

Figure 2 – Pre-test score distribution



Does learning chess have a positive effect on math achievement?

The simplest estimate of the effect of the treatment offered by SAM is the difference between the mean score for the experimental and the control group:

Effect of chess on math = mean score experimentals – mean score controls =

= 63.1 – 58.1 = 5.0 (*t=5.56*)

This means that the students in the treatment group give 5% percentage points more (9.6%) of correct answers than the students in the control group. In a 28-item test, this means a difference of about 1.4 correct answers.

The difference in means in the post-test in principle is sufficient as a measure of effect. It is customary to control for the pre-test score for two reasons: it might correct for "unhappy" randomization (as in our case) and it reduces the standard errors. The basic regression model is:

Post-test score = $\alpha + \beta$ experimental dummy + γ pre-test score + ε

where the impact is the estimated value of β and randomization guarantees that the usual assumptions on the error term are satisfied. Controlling for the differences in the pretest, the average effect of the treatment goes up to 0.068, that is 6.8 percent more correct answers for the experimental with respect to the controls.

More informative is to express the impact through the simple formula of effect size:

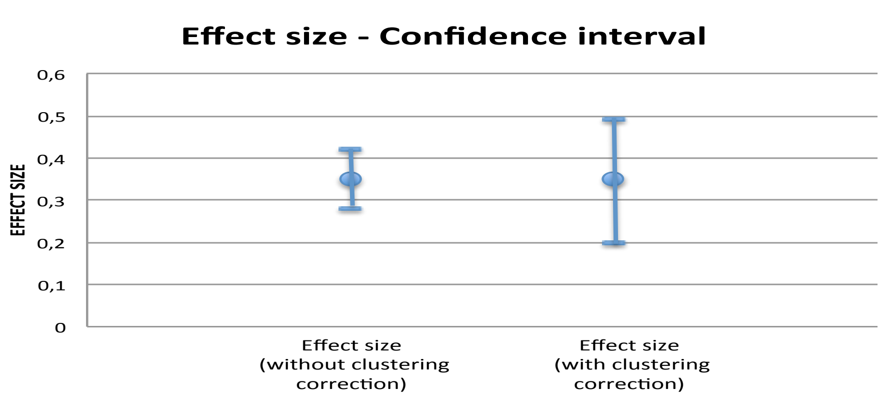
Effect Size = (Mean of experimental group – Mean of control group)/Pooled Standard Deviation

The effect size of SAM is 0.068/0.20 = 0.34

Therefore we can conclude that, based on our experiment, being taught how to play chess in 3rd grade improves on average math achievement by a third of a standard deviation. According to Lipsey, Bloom et al. (2009) an effect size greater than 0.25 is "educationally significant".

One more correction is in order. Until now we have computed the effect as the student observations were independent, but the intervention was made ad the class level, not at the student level. We have, therefore, to correct our estimates for the clustering at the classroom level. The estimate of the effect should not change, what changes is the precision of the estimate. The estimates were obtained with *clustering* routine available in STATA. The impact is still statistically significant, but the confidence interval widens as shown in Figure 3: now the effect size goes from 0.2 to 0.5, while before it went from 0.28 to 0.42.

Figure 3. Overall effect size without and with correction for clustering



Did some group gain more than others from SAM?

It is plausible that the effect is not homogeneous for all the students, but rather that some sub-groups gain more than others. In order to test that, we estimate a regression with an interaction term for each of the listed characteristics. The model is the following:

$$\text{Post test score} = \alpha + \beta \text{ Experimentals} + \gamma \text{ pre-test} + \delta \text{ characteristic X} + \zeta \text{CharacteristicX*Experim.}$$

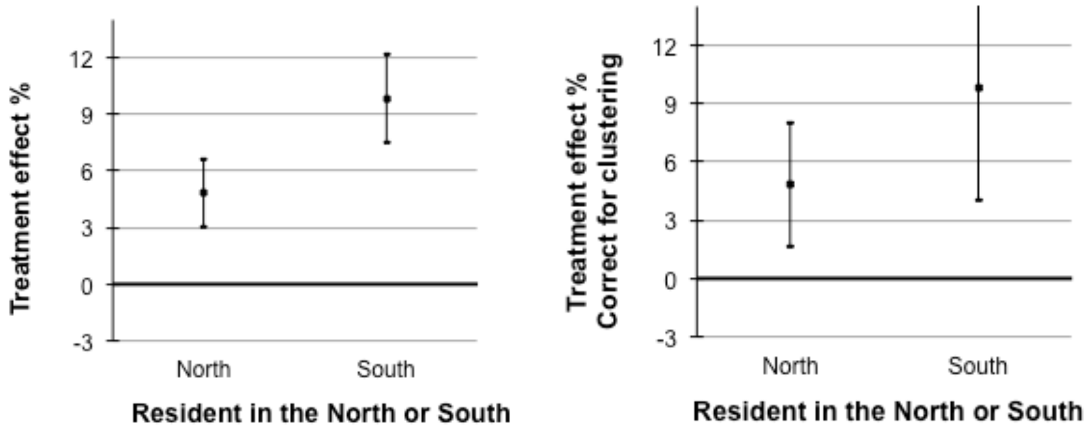
while β is the effect of chess for students without the characteristic, ζ is the differential effect for students with the characteristic of interest. The results are shown in Table 3.

Table 3 – Effect of Chess on Math Achievement: sub group analysis

Student Characteristic	*β*	*P-value*	*Interaction (ζ)*	*P-value*	*Effect for those with the characteristc*	*Effect size*
Male	*.065*	*0.000*	*.006*	*0.655*	0.071	*0.36*
Foreign born	***.065***	***0.000***	***.058***	***0.064***	**0.123**	***0.62***
Foreign-born parent(s)	*.066*	*0.000*	*.009*	*0.648*	0.075	*0.37*
Lives in the south	***.048***	***0.000***	***.047***	***0.001***	**0.095**	***0.48***
"I like math"	*.071*	*0.000*	*-.005*	*0.581*	0.066	*0.33*
"I do well in math"	*.068*	*0.000*	*.002*	*0.122*	0.070	*0.35*
"I know how to play chess"	*.061*	*0.000*	*.013*	*0.367*	0.074	*0.37*

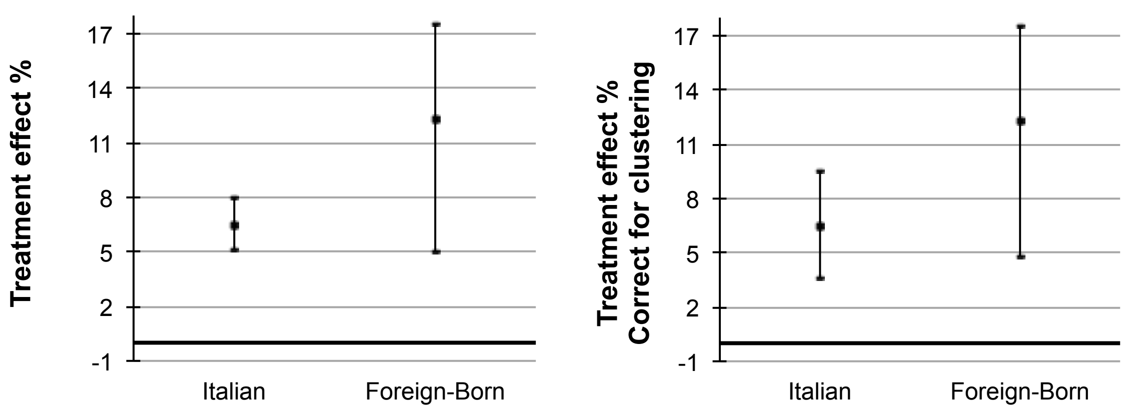
The only signifcant interactions are: foreign born and living in the south. A southern student shows an effect more than double than a northern student (9.5% versus 4.8%). The interaction becomes no longer statistically significant if we correct for clustering and the confidence intervals broaden as shown in Figure 4.

Figure 4. Confidence intervals for north-south residence, with and without correction for clustering



The students foreign-born show an effect almost double compared to the native Italian students: their performance improves by 12.3 percentage point more than the students in the control group, corresponding to an effect size of 0.62 (almost two third of a standard deviation), while Italian students shows an effect of 6.5 percentage point. Controlling for clustering doesn't change the interaction term: the foreign born students are spread in different classrooms so there is no clustering.

Figure 5 –. Confidence intervals with and without correction for clustering for the effects for Italian and foreign-born students



Cost of the intervention (Cost-effectiveness)

In the introduction we explained that SAM has been realized ‘on a shoestring’. Here we try to estimate the cost-effectiveness of the intervention at the “shadow-price”. These are “prices for goods and services that are supposed to reflect their true benefit and cost” (Rossi, Lipsey, Freeman. 2004).

The estimated at “shadow price” cost for 1,000 students is € 72,000 (these include instructors compensation, teaching materials, management costs. instructors’ professional development)

Cost for each student = 72,000/1000 = 72 €

Standardization in € 1000 unit = 72/1000 = 0.072

Cost-effectiveness = Cost per student/Effect size = 0.072/0.36 = 0.2

This represents the cost-effectiveness computing the overall effect-size. If we look at the two subgroups with bigger gains we have:

Southern students = 0.072/0.48 = 0.15

Foreign-born students = 0.072/0.62 = 0.08

Thus, teaching chess to foreign-born students appears to be the most cost-effective way to improve math performance.

Discussion and Conclusions

Attrition

The students at the pre-test where 1,996 (1,071 experimentals and 925 controls), and the two groups were equivalent, as we have shown in the equivalence study.

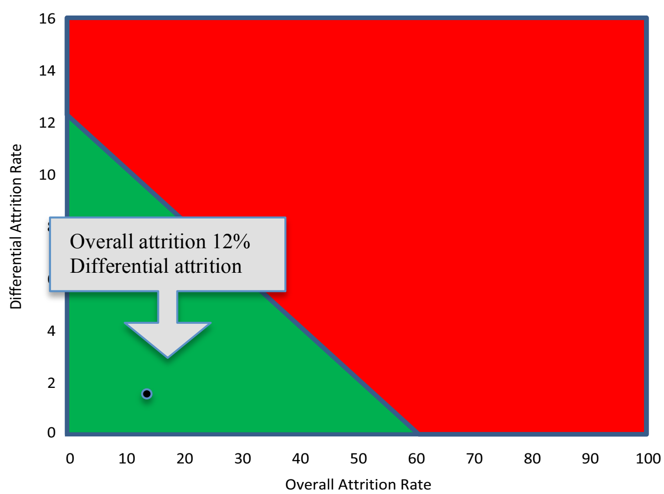
It is important to analyze the overall and differential attrition between the two conditions, because “*both contribute to the potential bias of the estimated effect of an intervention*” (What Works Clearinghouse, 2009)

At the post- test 1,756 showed-up, therefore the overall attrition rate is 12,02%. The differential attrition rate is 1,6% computed as:

Attrition for the experimentals = (1,071-950) / 1,071= 11.3%

Attrition for the controls = (925 – 806) / 925 = 12,9%

We used the What Works Clearinghouse diagram for attrition to benchmark SAM study. It falls in the green area, therefore the level of bias could be considered low according to the WWC guidelines (2009) , "*when the combination of overall and differential attrition rates cause an RCT study to fall in the green area on the diagram, the attrition will be considered "low" and the level of bias acceptable*".



Did chess learning displaced reading achievement?

SAM was implemented in the classrooms during school hours. At the moment we do not have information about the kind of activities that made space to chess instruction. The concern is that this could cause a displacement effect on reading. Some studies suggest that chess improve abilities in both reading and math abilities, but in future studies it will be necessary to test reading achievement as well.

Lack of external validity

The intervention was made using a preexisting network without general announcement and recruitment on large scale. All schools where volunteer and we do not have enough information to judge it they are representative of the overall population of Italian schools (or at least of the schools operating in the same area). Important development would be to randomly select schools within which randomly assign classes, providing incentive for school participation and eventually correcting for non- compliance

Concluding remarks

Despite a low budget, enthusiasm and commitment made it possible to mount a fairly well designed study. We hope it could serve as an example of how evidence can be gathered to improve the quality of education in Italy.

Bibliography

Berkman, R. M. (2004). The Chess and Mathematics Connection: More than Just a Game. *Mathematics Teaching in the Middle School*, *9*(5), 246-250.

Buki, J., & Ho, F. (2008). The Effect of Math and Chess Integrated Instruction on Math Scores | PRLog. *The Chess Academy*. Retrieved from http://www.prlog.org/10086633-the-effect-of-math-and-chess-integrated-instruction-on-math-scores.html

Campitelli, G., & Gobet, F. (2008). The role of practice in chess: A longitudinal study. *Learning and Individual Differences*, *18*, 446-458. doi:10.1016/j.lindif.2007.11.006

Ferguson R. (1983). "*Developing Critical and Creative Thinking Through Chess*",

Hong, S., & Bart, W. M. (2007). Cognitive Effects of Chess Instruction on Students at Risk for Academic Failure. *International Journal of Special Education*, *22*(3), 89-96.

Lipsey M., Bloom H., Hill C., Rebeck Black A. *How Big is Big Enough? Achievement Effect Sizes in Education*. University of Pennsylvania Graduate School of Education, February 2007.

Liptrap J. M. (1998). Chess and Standard Test Scores

Marguiles S. (1991) "*The Effect of Chess on Reading Scores: District Nine Chess Program Second Year Report*" Ph.D. dissertation. Retrieved from http://www.givewell.org/files/Analysis/margulies.pdf

Rossi, P. H., Lipsey, M. W., & Freeman, H. E. (2004). *Evaluation. A Systematic Approach. Seventh Edition*. Thousand Oaks, CA: Sage.

Scholz, M., Niesch, H., Steffen, O., Ernst, B., Loeffler, M., Witruk, E., & Schwarz, H. (2008). Impact of Chess Training on Mathematics Performance and Concentration Ability of Children with Learning Disabilities. *International Journal of Special Education*, *23*(3), 138-148.

Smith, J. P., & Cage. Bob N. (2000). The Effects of Chess Instruction on the Mathematics Achievement of Southern, Rural, Black Secondary Students. *Research in the Schools*, *7*(1), 19-26.

Sweller, J. & Clark, R.E. Kirschner, P.A. (2006). *Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry based teaching*. Educational Psychologist, 41, 75-86.

Thompson M. (2003). *Does the playing of chess lead to improved scholastic achievement?* Issues In Educational Research, Vol 13, 2003. Retrieved from http://www.iier.org.au/iier13/thompson.html

What Works Clearinghouse (2009). *WWC Quick review protocol. Version 2.0* . Retrived from http://ies.ed.gov/ncee/wwc/DownloadSRG.aspx