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Abstract: In this paper we present the context and results from a study, with 3rd to 6th grades children, about the relationship between chess and problem solving involving geometric and numeric patterns. The main result of this study is the existence of a relation between strength of play and patterns involving problem solving. We have included in the beginning an analysis of chess as a context for elementary mathematics problems, also showing its richness historically.

Keywords Strategy games; Chess; Problem solving, Patterns; Primary and middle school; Correlational study.

Strategic games and patterns in the curriculum of elementary teaching

The Principles and Standards for School Mathematics point to the identification of patterns and the use of strategic games, in the mathematics teaching (NCTM, 1991). Keith Devlin (2002, p.12) defines mathematics as being "the science of patterns". In addition, the document of the fundamental competences for Elementary School published by the Department of Basic Education in Portugal defines mathematics as the science of regularities (DEB, 2001). This document stresses the identification and exploration of patterns, as we can see from its continuous allusion in several topics of mathematics curriculum: numbers and operations, geometry algebra and functions. For each of these fields, mathematical abilities to develop in the Elementary School are explicit: "the predisposition to recognize numerical patterns in mathematical and not-mathematical situations (…) the aptitude to recognize and to explore geometric patterns (…) the predisposition to recognise patterns and regularities and to formulate generalizations in different situations, in numeric and geometric contexts".

The Curriculum of Elementary Teaching Mathematics points to the use of strategic games in problem solving context. Children like to play games and teachers must make use of the benefits of games environment to promote mathematics education. Chess is pointed as one of the games that increase "the capacity to accept and to follow a rule; the development of the memory; the agility of the way of thinking; the aim for challenge; the construction of personal strategies" (DEB, 1998). The curriculum also stresses the importance of the strategy games in the development of problem

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solving abilities. And it also points that strategy games contribute for the development of mathematical capacities, connecting reasoning, strategy and reflection with challenge and competition in a very rich and playful form (DEB, 1998).

Chess studies: some conclusions

There are several studies about chess and its implications on children education. In those studies the main conclusions are that chess promotes academic performance, especially problem solving strategies, increases memory, concentration, scores in IQ tests, critical thinking, and develops visual and spatial abilities and the capacity to identify patterns (Liptrap, 1998; Dauvergne, 2000 Thompson, 2003; Stefurak, 2003; Brenda, 2003). Studies focusing on the effect of children playing chess, disclose that chess players develop critical thinking, self-confidence, self-respect, concentration (Stefurak, 2003), and problem solving skills (Dauvergne, 2000).

The mathematics curriculum in Canada make use of chess to teach logic from grades 2 to 7 and with this curriculum problem solving scores improved from 62% to 81% (Liptrap, 1998).

Fergunson describes a study from Venezuela that relates improvement in most students IQ scores after only 4.5 months of systematic chess study. The results of this study led the Venezuelan government to introduce chess lessons at schools, since 1988/89 (Dauvergne, 2000).

A study by Murray Thompsom (2003) disclosed a significant effect between playing competitive chess and better academic performance, relating that best students tend to have also better IQ levels. However, it relates the possibility of playing chess contributing to students IQ, being the benefit of chess playing absorbed by the variable IQ. This researcher claims that playing competitive chess demands great skills of concentration, logical thinking and of projecting possible positions of pieces, helping to develop visual and spatial abilities. The van Hiele Model of Geometry Thought asserts that children learn geometry sequentially through five levels of understanding, being the first one, the level of visualization, where children understand the shapes for its appearance, as total entities. In elementary school teachers must help students to move from the visual level to the level of analysis (according to van Hiele Model), carrying on activities that develop the capacity of visualization (Ponte & Serrazina, 2000). A way for this development is the game of chess.

The speed of visual perception requires multiple and codified settings, being important the capacity to codify information and to identify significant places to focus attention. And it happens that experienced chess players memorize positions with a bigger number of pieces than less experienced players (Charness, Reingold, Pomplun & Stampe, 2001).

The study

The goal of this study concerns the verification of a relationship between the game of chess and patterns. More specifically, it is intended to identify the capacity to solve problems based on patterns, of chess players and of non chess players, to verify the relation between this capacity and the capacity to play chess. We also intend to identify the relation between these capacities and age, schooling years, gender and mathematics grades.

Methodology was based on a quantitative paradigm, with a correlational design. According to Cohen and Manion (1989), correlational studies are appropriate in educational research when there is a need to discover or clarify relationships and little or no previous research has been undertaken.

In fact, "*the investigation and its outcomes may then be used as a basis for further research or as a source of additional hypotheses*" (Cohen & Manion, 1989, p.161).

The sample of this study was constituted by 437 students from 3rd to 6th grades. To collect data the following instruments were used: a questionnaire and one test on problem solving based on geometric and numerical patterns that was constructed and validated for this study.

The following research questions have been followed:

1. Is there a relationship between playing chess and solving problems involving patterns?
2. Is there a relationship between solving problems with geometric patterns or with numeric patterns and playing chess?
3. Is there a relationship between solving problems based on patterns and age, schooling year, gender and mathematical levels of achievement?

Now we are going to identify the variables used in the research and explain how they have been implemented. Problem solving capacities that involve patterns have been investigated using a test constructed and validated for this study. The capacity to play chess was measured through the ELO rating of the players, as published by the chess federation, at the time when the test was implemented. ELO rating is a "quantitative system based on exponential smoothing of a player's rating depending on the actual proportion of victory compared with that expected given the rating of the opponents. (…) there is a direct relationship in the difference between two players' rating and their chance of victory – irrespective of the magnitude of the players' ratings. Thus a player who is ranked 100 points above an opponent will have a 64% chance of victory" (Clarke & Dyte, 2000, p. 586)

To collect data for the variables play chess, age, schooling year and gender we used a survey. The school grades in mathematics information were measured using the 1st assessment of the year.

The population of this study consisted of students from 3rd to 6th grades, chess players and students with school chess. This population was organized in the following way: students from 3rd to 6th grades from Braga; chess players and students with school chess from clubs of several areas of Portugal. There were involved 380 students from 3rd and 4th grades and 368 students from 5th to 6th grades.

The option for this selection was based on the proximity of schools to the residence of the researcher together with the opportunity to find chess players in national competitions. This extensive population contributed to a sample with a significant number of students. It must be clarified that chess players also included students with chess in school who participated in chess competitions. As instruments to collect data we used a survey and a test. The test included problems that included numeric and geometric patterns.

In the elaboration of the questions the following structure was used:

- identification of the following element of a pattern;
- identification of the element that doesn't fit in the pattern;
- producing patterns.

This structure was based on the structure of similar questions used by other authors, such as Krutetskii (1976). It is also based on the conclusions of Krutetskii's research, stating the existence of three types of mathematical ability: analytical, geometric and harmonic (combining the other two). The test was validated by a panel constituted by two university teachers of mathematics, one teacher of mathematics of the 2nd cycle and one 1st cycle teacher specialized in mathematics. From the analysis of the test by the elements of the panel we have selected 26 questions.

A pilot application of the test was made on a sample of 105 students: 20 from 2nd grade, 23 from 3rd grade, 22 from 4th grade, 23 from 5th grade and 17 from 6th grade. The lesser number of pupils from 6th grade is explained by the fact that three pupils have missed classes on that day. The test has been implemented by the researcher.

The elaboration of the test correction criteria was based on the principles reported by Charles, Lester and O'Daffer (1992) in the point "Analytic Scoring Scale". The scoring of the test was a very difficult moment that demanded organization and persistence due to the great number of questions: 437 tests with 24 questions, totalizing 10488 questions to score (excluding the pilot test). To ascertain test reliability we used Cronbach's Alpha, which measures the internal consistency of items. Cronbach's Alpha must be greater than 0.70. However, there are some references accepting values lower than 0.70 (Santos, 1999).

Initially, with 105 pupils and 26 questions, Cronbach's Alpha was 0.835. However, considering school grades, it was verified that for the 2nd year Cronbach's Alpha was just 0.217. The value of the Cronbach's Alpha has to be at least 0.70 (Fraenkel & Wallen, 1990) and the value for the 2nd grade would be far too below of the recommended value. Removing this grade, Cronbach's Alpha got a value of 0.756. To improve the reliability level we decided to remove two questions: question 5a) of the first part (P5a) and question 2 of the second part (S2). Removed these two questions, we analyzed the value of Cronbach's Alpha. The Cronbach's Alpha established was 0.763, a value appropriate to start the study.

To test the reliability of the scorer we used 30 tests. After the interval of one month between ratings the correlation coefficient was 0.99, significant at the 0.01 level. With this value we had good conditions to continue scoring tests.

The statistical treatment was done using SPSS for Windows, version 13.0. In the analysis, different statistical procedures had been used, adjusted to each case. Cronbach's Alpha was used to measure internal consistency. To test normality, that is, to verify if the distribution of data was parametric, we used the Kolmogorov-Smirnov test. To observe the correlation between problem solving involving patterns and the ELO of chess players we used the Pearson (r) coefficient, when the data was parametric, using the square of this coefficient (R^2) for interpretation (Field, 2000). R^2 can be interpreted as a ratio (Chen & Popovich, 2002). When one of the variables was dichotomic, as in gender, we used the point-biserial correlation (rpb) coefficient (Field, 2000). The Spearman coefficient was used when the distribution of data was non parametric, since it is not affected by the asymmetry of the distribution. Kendall's Tau (τ) coefficient was used for the variables school year and levels of achievement in mathematics, as they contain a considerable amount of ties.

The partial coefficient correlation was used to verify the correlation between the total classification obtained on the test and ELO, controlled by age, school year, gender and levels of achievement in mathematics. To make the interpretation of the correlation coefficients we used the following boundaries:

- Correlations between 0.2 and 0.35 reveal a small relationship between variables, too small to make predictions;
- Correlations between 0.35 a 0.65 are often found in educational research. They may have theoretical and practical importance depending on context. They allow for group predictions (Cohen & Manion, 1989; Fraenkel & Wallen, 1990).

Results of the study

In this study we intended to investigate the existence of a relation between a number of research variables. Now we are going to answer to each of the research questions. Nevertheless, it is also important to describe in more depth some results out of the scores students have obtained in the test.

Test results

The capacity to identify patterns was measured after one test that was constructed and validated for this study. It was verified that pupils were able to identify patterns, according to the test average. Concerning each of the parts of the test (geometric and numerical) we could notice that students, in general, had no difficulty in answering to the first part, and the pupils of 3rd grade exhibited great difficulties in the second part of the test. We have also verified that the score on the test in average increases as the school year increases. Analyzing the test scores in function of playing chess, we have verified that chess players had better scores in the test, being more evident using the scores of the second part of the test. Therefore we can mainly conclude that students that play chess appear to be the ones that better identify patterns. And more precisely, students that are chess players do identify numerical patterns better than those that do not play chess. In turn, we conclude that differences in the identification of patterns between players and students that have school chess are not significant. In this research we have also verified that most students discover geometric patterns more easily than numeric patterns. Inversely, chess players find more easily numerical patterns.

Playing chess and solving problems involving patterns

As to the relationship between the capacity to play chess and solving problems involving patterns, some conclusions were drawn:

a) Strength of play is positively related to problem solving involving patterns with a coefficient of correlation $r = 0.458$ (table 1);
b) School grade affects the relationship between strength of play and problem solving based on patterns. However when we exclude its effects, still the relationship is above 0.38;
c) Age and gender affect slightly the relation between strength of play and problem solving involving patterns. But its effects are not significant.

		Total	EloTeste
Total	Pearson Correlation	1	,458**
	Sig. (1-tailed)		,000
	N	437	65
EloTeste	Pearson Correlation	,458**	1
	Sig. (1-tailed)	,000	
	N	65	65

**. Correlation is significant at the 0.01 level (1-tailed).

Table 1: Correlation between test scores and ELO rating

Taking into account these results we can conclude that playing chess well seems to constitute a good foundation to identify patterns. This is in conformity with the recommended to use strategy games in the curriculum.

Playing chess and solving problems involving numeric and geometric patterns

The capacity to identify geometric patterns was measured using the first part of the test and the capacity to identify numerical patterns using the second part. As to the capacity to identify geometric patterns we can conclude that it was positively related with strength of play. However it is a not too strong relation. As we can observe (table 2) the correlation coefficient is $r = 0.320$.

		somaP	EloTeste
somaP	Pearson Correlation	1	,320**
	Sig. (1-tailed)		,005
	N	437	65
EloTeste	Pearson Correlation	,320**	1
	Sig. (1-tailed)	,005	
	N	65	65

**. Correlation is significant at the 0.01 level (1-tailed).

Table 2: Correlation between the scores of the first part of the test and ELO rating

Concerning the capacity to identify numerical patterns, we can conclude that it is also positively related to strength of play and this relation is stronger than the preceding. As we can see in table 3, a correlation coefficient of $r = 0.463$ between strength of play and the capacity to identify numerical patterns was obtained.

		somaS	EloTeste
somaS	Pearson Correlation	1	,463**
	Sig. (1-tailed)		,000
	N	437	65
EloTeste	Pearson Correlation	,463**	1
	Sig. (1-tailed)	,000	
	N	65	65

**. Correlation is significant at the 0.01 level (1-tailed).

Table 3: Correlation between scores of the second part of the test and ELO rating

Based on these results we can conclude that there is a relationship between the ability to solve problems involving numeric or geometric patterns and the ability to play chess, being stronger in the case of numerical patterns.

Relation between solving problems based on patterns and age, school grade, gender and mathematics levels of achievement

Concerning the third research question, we are now going to put forward some conclusions on the relations between solving problems based on patterns and age, school grade, gender and mathematics levels of achievement. As a result, we can conclude that:

a) Playing or not playing chess has no relation with problem solving involving patterns ($r = 0.13$);
b) There's a weak negative relationship between the ability to solve problems involving patterns and students date of birth ($r = -0.25$);
c) There's a weak positive relationship between the ability to solve problems involving patterns and school grade ($r = 0.23$);
d) Belonging to feminine or masculine gender is not related to the ability to solve problems involving patterns ($r = 0.03$);
e) There's a weak relationship between the ability to solve problems involving patterns and mathematics levels of achievement ($r = 0.22$).

Conclusions

The results of this study do not allow us to go outside the population of elementary school students, being pertinent for the studied population. Teaching students to play chess well may constitute a strategy to help students to identify patterns. Therefore we think that it would be desirable that teachers invest on chess systematic teaching so that their students become better players, and in order to respect curriculum guidelines. However we are aware that no implications can be set between the two, and more research should be developed in order to construct such implication.

The test reveals that, inversely to others students, chess players perform better on numerical patterns rather than on geometric patterns. We think it has become relevant to look for the reasons inherent to this difference. Why good chess players identify numerical patterns better than others students? The answer to this and other questions could be the aim of new research. Finally, chess is not the only strategy game. And the Curriculum of Elementary Teaching also refers to others games like draughts and mastermind. Would these games have the same results as we had with chess? We recommend more research in order to find analogous relations between other strategy games and problem solving involving patterns.

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