Chess Playing and Mathematics: An Exploratory Study in the South African Context

Luneta Kakoma[1,2] and Apostolos (Paul) Giannakopoulos[1,2(✉)]

[1] University of Johannesburg, Johannesburg, South Africa
kluneta@uj.ac.za, gianna@unisa.ac.za
[2] University of South Africa, Pretoria, South Africa

Abstract. In 2014 the University of Johannesburg undertook a study into the role that chess plays in the learning of Mathematics. According to authors' knowledge, it is one of the biggest studies undertaken which involved 10 teachers and about 1800 learners. The study although it was predominantly exploratory, it is also to some extent confirmatory as it involved also some control schools as well as comparative as it also involved an Ugandan school. The uniqueness of the South African situation which lies between a First World and a Third World country offers some new insights into the role that chess plays in the teaching and learning of mathematics. Preliminary results show that there is a correlation between playing chess and the learning of Mathematics.

Keywords: Mathematics · Foundation phase · Chess · Transfer · Critical thinking · Problem solving

1 Introduction

The use of games in general and use of chess in particular in the teaching-learning situation is not something new. Back in the 60s a psychologist, Adrian de Groot [1] became very interested in the use of chess as an educational tool. He observed particularly that there was a significant different approach between the 'experts' (grand masters)' and the new to the game, the 'novices'. He assumed that the latter under the guidance of the former they will also become experts.

In the early 80's Foundation (ACF) introduced chess in schools in order to improve the mathematical skills of the learners through critical thinking and problem solving skills which are evident in a chess player. In South Africa the MiniChess programme (MCP) [2] was introduced in some disadvantaged primary schools in Grades R to 3, having the backing of the Russian Grandmaster Gary Kasparov. In South Africa alone it has trained more than 1300 teachers since 2008 and it is active in more than 170 schools [2].

The University of Johannesburg in collaboration with MCP undertook to investigate the effects of chess on Mathematics for Grades R-3. This paper reports on this study that took place in 2014 and was a predominantly exploratory and partially confirmatory. The results will form the basis for the next phase, the intervention phase in 2015.

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2 Literature Review

The role of playing games in order to enhance teaching and learning has been researched for more than 50 years. The results have been inconclusive [3–5]. There can be many reasons for it and the most important one could be the problem of transfer. Although a lot of research [3, 6] has been done on transfer it still remains an elusive concept. There is no single definition of transfer as it depends on the context. For example, transfer within a domain or in different domains [6], transfer of knowledge and skills [5], transfer of training [7] ability to generalize, or transfer of knowledge to solve problems in novel situations [8]. Failure by the learner to see the analogy or the novelty of the new situation, leads to unsuccessful transfer of his/her existing knowledge [9]. For Billing [6], problem-solving, learning and transfer are similar cognitive activities.

Gobat and Campitelli [3] pose the question that most experts on transfer have posed in general: "Can a set of skills acquired in a specific domain (in our case chess) generalize to other domains (e.g., mathematics, reading) or to general abilities (e.g. reasoning, memory)?" There is no agreement between researchers if that is possible or not. This study is not trying to answer this question directly but it is based on evidence that chess can enhance various cognitive abilities.

Billing [6] conducted an extensive research on transfer where he surveyed 700 analytical and evaluative papers with good empirical evidence to back up any claim where the tasks were of high cognitive content. His conclusions could be summed up by Alexander and Murphy [10] (cited in [6]). These authors state that educators should take cognisance of one of the generalisations on transfer that …transfer of knowledge and procedures learned through instruction occurs far less often than educators hope; and that there are three components involved in transfer: the learner, the content and the context. These two important findings also form part of the essence of this study.

2.1 Chess and Mathematics

As it was stated earlier de Groot [1] was one of the first to see the importance of chess as an educational tool and others [3, 10, 11]. Research by Christiaen [12], Fried and Ginsburg [11] and others [5, 13] found that learners receiving instruction in chess had gained an academic advantage over the control group not receiving instruction in chess, even cognitive, perceptual-motor, and emotional gains. At the center of chess playing is thinking, intuitive and conscious, and training children to think from an early stage can only improve their cognitive abilities [13].

In the '80s it was the ACF embarked on the Chess in Schools programme as it was established then that learners that engage in chess regularly their maths scores improved by about 18 %. Research done by a number of authors [13–15] came to regard chess as a model for cognitive processes and abilities such as perception, information management, attention, memory, logical thinking and problem solving. Playing chess also involves a combination of aptitudes, such as analysis, logical and critical thinking. It means that ability in chess is not due to the only one or two abilities of individuals but due to a large number of aptitudes that work together [5, 13].

According to Feldhusen et al. [16] they also highlighted a number of benefits of studying and playing chess, not just for gifted children: it raises intelligence quotient (IQ) scores, strengthens problem solving skills, teaching how to make difficult and abstract decisions independently; enhance reading, memory, language, and mathematical abilities.

Gaudreau [17] further showed the value of chess for developing problem-solving skills also among young children. Using "Challenging Mathematics", the average problem solving score of students increased from 62 % to 81 %. Another study by Liptrap [5] and others [13, 18] also showed that chess can improve both reading scores and mathematics for elementary students.

Another view is that learning chess develops some sort of informal handling of mathematical concepts which might be better than formal learning [18]. In the framework of Barrett and Fish [13], without knowledge about the concept of joint probability, chess-playing children excellently performed in calibration tests.

However other studies conducted proved that, the benefits of chess in learning in general and mathematics in particular is questioned. Most of the studies based their argument on the claim that chess masters had the ability to store innumerable configurations and the best moves associated with each in long-term memory rather than having developed superior problem solving skills [4, 18]. This argument though could be true for grown up players and not for children at Foundation phase where playing any form of game does carry educational value. The only question is 'To what extent?".

Based on the benefits that chess has in the learning of Mathematics in South Africa the MiniChess Association [2] brought chess playing to some disadvantaged primary schools as an additional form of enhancing the learning of Mathematics. In order to evaluate the effects of chess on the teaching and learning of Mathematics at Foundation levels the following research was conducted.

3 Research Methodology

The study was a predominantly exploratory quantitative quasi-experimental study. Since it involved 10 primary schools and 1800 learners and it was the first of its kind in South Africa of such a great scale, it was decided by the researchers to divide it into three phases. In 2014 Phase I is reported here. Phase II for 2015 will be the interventionist phase and Phase III in 2017 the evaluation phase.

It was also decided that 4 schools could be used as control schools (See Table 1, No 7-No10) in order to get a preliminary idea about chess playing schools and non-chess playing schools. These schools' Grades wrote the test of the previous Grade. For example Grade 1, wrote the standarised test of Grade R. Grade 2 wrote the standarised test of Grade 1 and so on. Furthermore, since MiniChess [2] it was used for a comparative study. For anonymity sake schools were numbered as No 1- No 10. The experimental schools had 1 h of chess every week. At the end of the course all schools wrote standarised tests supplied by the South African Department of Basic Education (DBE) [19] where copies of the tests can be obtained.

Table 1. Standarised tests results per school

Schools	N	R	N	Gr1	N	Gr2	N	Gr3
No 1	74	67	60	65	63	59	62	46
No 2	69	78	75	71	36	29	81	31
No 3	39	72	40	70	46	64	48	35
No 4	56	64	65	65	24	56	45	38
No 5			43	29	20	30	45	19
No 6	27	47	43	46	20	29	24	6
Ave (excl 6)		70		60		46		34
No 7	77	72	64	57	60	46		
No 8	64	61	54	50	57	46		
No 9			147	53				
No 10	64	63	59	61	58	50		
Aver.		65.3		55.3		47.3		
Totals	470		650		384		305	

The study being predominantly exploratory as stated earlier, as it tried to establish the competency of the learners in the various sections of mathematics it also worked on the hypothesis that chess can have a positive effect on the learning of mathematics, as a result control (non-chess playing schools) and experimental groups were also used.

The Method. None of the 10 schools used had chess in their schools before. The Mini-Chess Association provided trainers who trained the teachers in the use of chess for educational purposes. The course comprises of 4 levels one for each Grade (R-3) In most of the cases mathematics is 'camouflaged', as it is implicitly involved as well as various cognitive functions like, decision making, logic, anticipating and so on.

In school No 9 only Grade 1 participated in the experiment while in school No 5 Grade R did not participate and school No 6 is the Ugandan school. From the control schools, in school No 8 only Grade 1 test was written. The tests comprised of 57 items for Grade R, 97 items for Grade 1, 107 items for Grade 2 and 97 items for Grade 3. In addition to the tests interviews were conducted with the teachers from the six schools that participated in chess.

The Results. In Table 1 the results from the standardised tests appear with N the number of learners in each grade and school and the other columns represent the average marks for all Grade R- Grade 3 for each school (No1–No10) as some schools had more than one class in a certain grade. For example, school's No1 all Grade R learners obtained an average of 67 % while for school No 6 all Grade 1 learners obtained an average of 46 %. The averages of the experimental and control schools is also shown where for the experimental group were 70 % (Gr R), 60 % (Gr 1), 48 % (Gr 2) (excluding the Ugandan school) and the corresponding averages for Grades R-2, 65.3 %, 55.3 % and 47 % respectively. The total number of number of learners that participated was 1809.

4 Analysis of Results and Performance on Various Mathematical Concepts - Summary

Since this study was predominantly exploratory and many schools were involved it was decided to look for trends first and then look for important points that explain the effects if any in the teaching and learning of Mathematics if chess is used as a way to enhance various cognitive abilities. Performances between the schools were not analysed as that was not part of the research aim.

- For both experimental and control groups there is a decline on the average performance from Grade R to Grade 3. This means that as the learners were advancing in their grades their knowledge of mathematics was declining.
- The highest correlation between experimental and control groups occurs in Grade 3 where the averages are the lowest for both groups
- The lowest correlation occurs in Grade 2 where the experimental schools performed slightly worse than the control groups.
- The Ugandan school performed worse than all schools.
- Where the number of learners was low (less than 45) these schools performed better. This means that the less the number of learners in class the better their performance in Mathematics.
- Having used t-tests for the experimental and control groups the calculated values of t were -1 08, -0.57 and 25.30 for Grades R, 1 and 2 respectively. These were significant at $p > 0.2$, $p > 0.2$ and $p > 0.00$ levels.

All school underperformed in Grade R.(less than 40 %) on a number of questions especially those that required providing an explanation. On average less than 40 % was achieved in all the grades from 1 to 3. This points to an alarming picture about mathematics in the country. This study concurs with other studies that have established that learners' mathematical knowledge is very weak in all grades.

For Grade R the concepts that were identified as problematic were: writing numbers correctly, vocabulary, shape recognition, telling time. For Grade 1, shape recognition is still a problem as well as time telling. In addition to these, describing fractions of shapes using mathematical symbols, problems with, $>$, $<$, $\geq$, and $\leq$, and data handling and graphing were problematic.

In Grade 2, some learners can still not write the numbers from 1–100, or identify what the next number is, estimation, time telling, equality and inequality and place value which creates problems with arithmetic operations. Data handling is still problematic as well as sequencing days of the week and matching shapes with their corresponding names.

Finally for Grade 3, estimation, place value, long multiplication, difficulty in using comparative words such as 'more than', 'less than', symmetry, and more than 65 % could not name polygons.

4.1 Analysis of Teachers' Interviews

Teachers from the 6 experimental schools were interviewed at the end of the year, and below is a summary of what they said.

- The teachers all agreed that learners loved MiniChess and were very enthusiastic and motivated about it;
- The teachers have noticed that learners seem to have improved in their attention span as they stay quiet longer tan before;
- The teachers admitted that the learners social skills have improved;
- Almost all the teachers agreed that they do not see the link between chess and the curriculum;
- The teachers suggested that MiniChess must be part of the school curricula;
- The majority of the teacher confessed that they still cannot play chess and relied on the facilitators to instruct the learners.

5 Discussion and Future Directions

The study produced some encouraging results. This was due to the fact that there is sufficient ground to accept the hypothesis that chess playing enhances problem solving skills and concept formation. Huge problems were encountered with sequencing, pattern recognition, matching words and shapes or shapes that share same attributes (square and rectangle) contrasting them to other shapes (i.e. circles). Fractions (numerical and two dimensional shapes) also posed problems.

A number of uncontrolled variables could also have contributed to less than expected performance:

(a) The teachers
   - The training of teachers, how they use chess and incorporate it to mathematics.
   - Teachers themselves are not conversant with chess.
   - It is possible teachers treated chess as a game for recreational purposes.

(b) The trainers of the teachers
   - The training of teachers was not monitored by the researchers. As a result it is possible that the training of the teachers could have been flawed.
   - The trainers themselves were not educationalists.

(c) Other factors
   - The Principals of the schools allowed only one afternoon a week for chess. Perhaps after school the children were too tired too.
   - The length of the standarised tests could have been a bit long as in some schools they could only finish 80 % of the test.

In order to move to the second phase, the intervention phase, it is necessary firstly to collect more data from teachers and learners through interviews and focus group interviews. Then analyse in more detail all concepts that many learners have a problem with and design interventions to improve learning. Teachers will receive particular training to teach such concepts rather than reaping the benefits of playing chess indirectly.

For example existing chess materials will be directly connected to mathematics. Then in the midyear learners could be retested and the results will be processed. At the end of the year based on the findings, new mathematics materials can be developed which connect more chess playing and problem solving.

The following year the process will be repeated and finally materials can be developed to be part of the school curriculum. In Grade R and Grade 1 it might be a good idea to translate the English concepts to some vernacular to remove the problem of language as a barrier to learning since Foundation phase learners are taught mostly in their vernacular. The research team agreed that it is almost impossible to conclude from the learners' one year engagement with MiniChess that it had a definite bearing on their mathematical growth. The research team will:

- Investigate the cognitive development of the learners over a period of two years.
- Develop mathematics questions that attend to problem-solving, critical and strategic thinking
- Investigate the learners' growth in mathematical competence over the period of two years.
- Develop learners and teachers' support materials that link chess to the mathematics curricula and give appropriate training..

6 Conclusion

Introducing chess at an early stage of a child's development could have positive effects in the teaching and learning of mathematics especially in a developing country. However for it to succeed it is absolutely necessary to train primary school teachers as to how to use chess as a supplementary tool to enhance various cognitive functions (and there is evidence to that effect) but also using chess as a game for recreation, numeracy, two dimensional thinking, logic and viewing mathematics critically.

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