SciVerse ScienceDirect

Procedia - Social and Behavioral Sciences 32 (2012) 372 – 379

Procedia
Social and Behavioral Sciences

4th International Conference of Cognitive Science (ICCS 2011)

Investigation the impact of chess play on developing meta-cognitive ability and math problem-solving power of students at different levels of education

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Abstract

The aim of this study was to analyze the effect of learning of chess play on developing meta-cognitive ability and mathematical problem-solving capability of students at various levels of schooling. To this end, 86 school-boy students were randomly selected and they taught chess for six months, and another group of 94 students randomly selected for control group. The subjects were assessed via meta-cognitive questionnaire of Panaoura, Philippou, and Christou (2003) and mathematics exams. The results indicated that chess player students showed more achievement in both meta-cognitive abilities and mathematical problem solving capabilities than other non-chess player students. In addition, a positive and significant relationship was found between students' meta-cognitive ability and their mathematical problem-solving power. These results suggest that we can use chess as an effective tool for developing higher order thinking skills.

Keywords: Chess play; metacognitive ability; mathematics; problem solving

1. Introduction

It is claimed that chess is an activity of boundless potential for the mind. Chess develops mental activities which are used throughout life. We may mention some of these activities such as problem-solving, focusing, critical thinking, abstract reasoning, strategic planning, analysis, creativity, evaluation and synthesis. As an instrument to teach problem-solving and abstract reasoning, we can use chess effectively. Learning how to solve a problem is probably more important than finding a solution for a specific problem. By means of chess, we learn how to evaluate a context and to this end, we should concentrate on the main factors and omit diversions. We may find original and imaginative solutions to accomplish the plan. Chess is very influential, since it is self-motivating. The game has attracted people for about 2000 years and the aims of attack and defense resulting in checkmate encourage us to penetrate into our mental store (Celone, 2001).

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1877-0428 © 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the 4th International Conference of Cognitive Science
doi:10.1016/j.sbspro.2012.01.056

Several studies have been done about the advantage of chess in education. The findings of the studies showed that chess can advance academic accomplishment, particularly problem solving strategies, enhance memory, focusing, score of IQ tests, critical thinking and creativity, it also augment spatial and visual power, and the ability to recognize patterns (Frank, 1974; Ferguson, 1995; Liptrap, 1977; Dauvergne, 2000; Thompson, 2003; Stefurak, 2003; Brenda, 2003; Ferreria & Palharse, 2008). Some researchers have endorsed the influence of chess play on advancing problem solving ability. Having found similarities between mathematical problem solving and chess, Horgan (1998) pointed out that chess is clearly a problem-solving instrument and the best possible way to analyze problem-solving and decision-making because it is a closed system with clear and determined rules. The first step in encountering a problem is to analyze it in an introductory and subjective way. Assessing the problem and perhaps trying to find patterns or similarities to prior experiences. Just as mathematics is the study of patterns, so in chess pattern recognition is very important in problem solving. By recognizing similarity and patters, we can formulate a general strategy to solve the problem which may include developing other choices and a creative process. A skillful chess player, like a good problem solver, has obtained a great number of relevant schemata; thus making it possible for good alternatives to come up. We can use a process of calculations- known as decision tree analysis- to assess these alternatives. Here the chess player or problem solver is calculating future happenings just based on solutions that are evaluated.

Problem solving capability is a complicated interaction between cognition and meta-cognition. Perhaps the basic source of trouble in problem solving is that the students can not actively watch, check and regulate the cognitive process they encounter upon solving the problems (Artzt & Armour-Thomos, 1992). Flavell (1971) developed the concept of storage of input, intelligent structuring and retrieval activity, notion of intelligent checking, and called such knowledge as generally a kind of "meta-memory" (p. 227). Meta-cognition is a persons' knowledge about his or her own cognitive processes and products. It is also active checking, following regulations and assessment of cognitive activities (Flavell, 1979). Brown (1987) divided meta-cognitive into two main categories: knowledge of cognition and regulation of cognition.

Knowledge of cognition is the information that is fixed, uncertain, late developing that human thinkers have as objects of consideration. Regulation of cognition is the activities used to check and monitor learning. These activities consist of planning activities (predicting outcomes, setting time strategies, and different forms of indirect trial and error, etc.) before solving the problems; checking activities (monitoring, testing, revising and resetting one's strategies for learning) in the process of learning and controlling outcomes (assessing the outcomes of strategic actions with the criteria of effectiveness and efficiency).

It has been shown that these activities are not usually stable, though in the past adults have used them on simple problems and are not fixed (knowing how to do something does not necessarily mean that one can bring the action to the level of conscious awareness and reporting to others). They are also independent of age, that is, task and situation dependent (Brown, 1987). One basic aspect of learning – which has also been ignored is that students have the necessary knowledge and skills to do complex tasks but they don't use them. Perhaps the reason is that students don't have motivation or confidence to use them and they do not accept that the situation demands using those skills (Hartmen, 2001). The different meta-cognitive skills are necessary for successful solution of any complicated problem-solving task. It is clear that people, who have higher level of meta-cognitive ability, do much better in problem-solving. They do their best to find out the relationship among the facts in a problem. They may check their accuracy, take apart complex problems toward simpler steps, and may ask themselves questions, and look for answers to make their thought clear (Panaoura et al., 2003).

Some evidence shows that chess play can enhance meta-cognitive skills and some other tasks that may be important for success during challenging tasks, such as mathematical problem-solving. About the influence of chess, Milat (1997) says:

- Chess increases intelligence creativity, enhances strategic thinking skills and enriches problem-solving ability. Furthermore, it increases self-esteem.
- Chess improves and develops higher order thinking skills (that is meta-cognitive skills); in addition youngsters evaluate the actions and results and predict future possibilities.
- When chess is highly practiced in specific countries, practicing students show ability to be among the top in math's and science and recognize complicated patterns as well.

Given the academic benefits of chess, Meyers (2005) asserts that "we have brought chess to school because we believe that it can directly contribute to academic performance. Chess makes children smarter. It does this function by teaching following skills:

- **Focusing**: children are taught to learn about the advantages of observing and focusing. In addition, children cannot respond to what is happening unless they watch it.
- **Visualizing**: children are encouraged to imagine a series of actions before it occurs by training and asking them to visualize and to move pieces in their mind, first one move, then several moves ahead.
- **Thinking ahead**: children are taught, first of all, to think and later to move on or act. We educate them to ask themselves "if I do this, what may happen later and how can I respond? Chess helps to develop calmness or attentiveness.
- **Weighing options**: children may learn they don't have to express whatever first occurs to their mind, they learn to find out other choices and take into account the advantages of different actions.
- **Analyzing concretely**: children learn to assess the results of particular actions and arrangements. Does this sequence help me or hurt me? It is better to make a decision based on logic instead of impulse.
- **Thinking abstractly**: children are taught to move back occasionally from details and pay attention to the whole pictures. They learn to apply patterns to various or related situations especially when they discover them in one specific context.
- **Planning**: children are taught to define long-term goals and do their best to achieve them. They feel the need to re-evaluate their plans particularly when new improvements change the situation. So our objectives in this study are to investigate the impact of chess play on developing meta-cognitive ability and math's problem-solving powers of students at different levels of education.

2. Method

The statistical population of this study was the male students of fifth, eighth, and ninth grade at primary and junior high schools in Sanandaj, in west of Iran. The statistical sample includes 180 students who were selected randomly among the schools. Having explained the research aims to the participants, 86 students were randomly selected and they were taught chess for 6 months along with routine activities of the school (experimental group or chess player students). The rest of the students who were 94 people, were put in control group or non-chess player students. The frequency of participants is showed in table 1.

Table 1. Frequency of the participants

	chess player students	**non-chess player students**
Fifth grade	28	29
Eighth grade	27	32
Ninth grade	31	33
Total	86	94

The questionnaire of meta-cognitive ability measurement, that is, Panaoura, et al. (2003), was used for all participants. The questionnaire consists of 30 metacognitive items designed on the basis of five-choice Likert-scale ranging from always, often, sometimes, rarely, to never and they are given points 5, 4, 3, 2,1 respectively. Maximum meta-cognitive score of the students was set at 150 and the minimum was 30. The reliability of the questionnaire, based on Cronbach's alpha is 0.82. The researcher-made math test was also applied to measure problem-solving ability of students at different educational grades. To design researcher-made tests, third international mathematics and science study questions (TIMSS), textbooks and non-textbooks, and math teacher experiences were targeted. In the end, three tests were selected and applied to participants based on their respective grades (educational levels). Maximum possible score for each student in the math test was 6.

3. Results

The results obtained from analysis of meta-cognitive questionnaires applied to the participants along with two independent samples suggest that there is a significant difference at the level $p < 0.01$ between meta-cognitive scores means of the chess player students and the non-chess player students ($t[178] = 5.08$, $p < 0.01$). These results are shown in tables 2.

Table 2. Results of independent samples *t*-test for comparing meta-cognitive score means between two groups

groups	n	*M*	*SD*	*t*	*df*	*p* (2-tailed)
Chess player	86	132.75	7.23	5.08	178	0.000
Non-Chess Player	94	125.56	9.93			

According to table 2, we can see that the meta-cognitive scores mean of chess player students was more than non-chess players (as much as 7.19) and this suggests that chess play, as an independent variable, has significant role in developing meta-cognitive ability of the students. In addition, the results suggest that the difference was significant for meta-cognitive scores mean of chess player students at $p < 0.01$ (for fifth grade), $p < 0.05$ (for eighth grade) and $p < 0.01$ (for ninth grade) students when compared with non-chess player students. The results summarised in table 3.

Table 3. Results of independent samples *t*-test for comparing meta-cognitive score means of students at different educational levels

Education level	Groups	n	*M*	*SD*	*t*	*df*	Significance level
Fifth grade	Chess players	28	134.80	7.73	2.71	55	Level 99% $p = 0.009$
	Non- chess players	29	124.57	10.49			
Eighth grade	Chess players	27	133.26	6.81	2.36	57	Level 95% $p = 0.02$
	Non- chess players	32	126.67	10.26			
Ninth grade	Chess players	31	133.10	7.31	3.76	62	Level 99% $p < 0.001$
	Non- chess players	33	125.09	9.30			

Although the result of the current study is indicative of positive effects of chess play on developing meta-cognitive ability of the students, there is little or no study in this respect to challenge our results or to support it even more.

Another result of this study is that, as Pearson Correlation test shows, there is a positive and significant relationship between meta-cognitive ability of students and their problem-solving power at $p < 0.01$ level. The Pearson correlation was 0.719 which signifies a strong relationship. This result is consistent with other research done in mathematics and meta-cognitive domain. Here, some of these studies are addressed briefly.

The results of various studies show that there is a positive and significant relationship between mathematical problems solving and meta-cognitive elements, that is, the more the students gain the power of meta-cognitive ability of problem-solving, the more the prospect of their success in solving challenging problems (Lester, Garofalo, & Krool, 1989; Schoenfeld, 1985; Gooya, 1992; Lucangli & Cornoldi, 1997; Pape & Smith, 2002; Kazemi, Fadae, & Bayat, 2010). According to Silver (1982) any learner and math teacher agrees that problem-solving ability involves more than just the accumulation of skills and techniques; in fact the capability to monitor the progress or process of problem-solving and knowing the limitation and ability of the individuals are also important. Silver called these "meta-cognitive abilities" (cited in Gooya, 1992).

Gooya (1992) pointed out that many researchers believe that the ability to make managerial or executive decisions may signify whether the person can be a problem-solver or not. She asserted that meta-cognition has an effect on problem-solving and the failure to assess individual strategies may result in failing to reach a reasonable conclusion. In this way, the behaviour or response of the person who knows the required and right strategies to solve a problem is justifiable or rational, though she/he may not be able to solve it. Schoenfeld (1985), in the process of observing beginner problem-solver, reports that such students have real knowledge and right strategies to solve the problems but their possible inability to find the answer to the problems is mainly due to their weak executive decisions. Panauora et al. (2003) believe that, those who have higher meta-cognitive power, are more meticulous and attentive in discovering or understanding the reality of problems. These people would evaluate their possible solution easily, analyze complicated problems in a detailed and specific ways and control their own thinking processes by self-asking.

The result of the researcher-made math test and applying T-independent samples test suggest that there is a significant difference at $p < 0.01$ between the mean of problem-solving score of chess player students and the non-chess player students ($t[178] = 2.89$, $p < 0.01$). Table 4, summarizes the results.

Table 4. Results of independent samples *t*-test for comparing math score means between two groups

Groups	n	*M*	*SD*	*t*	*df*	*p* (2-tailed)
Chess player	86	4.41	.93	2.89	178	0.008
Non-Chess player	94	3.74	1.01			

From the table 4, it is clear that the mean of the math scores of the chess player students was more than the non-chess player students; suggesting that chess play, as an independent variable, has a positive role on developing problem-solving ability of the students. Furthermore, the results suggest that the mean difference of math scores of chess player students was significant at $p < 0.05$ in fifth grade students, $p < 0.05$ in eighth grade and $p < 0.01$ in the ninth grade students when compared with non-chess player students. Table 5 summarizes the result.

Table 5. Results of independent samples *t*-test for compare of math scores means in different educational level

education level	Groups	n	*M*	*SD*	*t*	*df*	Significance level
Fifth grade	Chess players	28	4.44	0.9	2.13	55	Level 95%
	Non- chess players	29	3.79	0.83			$p = 0.03$
Eighth grade	Chess players	27	4.39	0.99	2.25	57	Level 95%
	Non- chess players	32	3.71	1.08			$p = 0.01$
Ninth grade	Chess players	31	4.37	0.95	2.72	62	Level 99%
	Non- chess players	33	3.68	1.11			$p = 0.004$

The result of this study is consistent with other research done in this respect. Here we review some of them briefly. In a study carried out by Gaudreau (1992), in New Brunswick, Canada, it was shown that there is a significant and extensive relationship between math skill and chess play. In this study which was done on 437 fifth grades of elementary students, chess was injected in the curriculum of concerned groups. The result of this study suggests that the students, who had participated in chess play, got higher scores in problem-solving activity. Thus the role of chess play was accepted as an instrument to enhance problem-solving among students. Accordingly, the researchers started to publish the texts called "challenging mathematics" and utilized chess for logical teaching of math to students from second grade to eighth grade of junior high school. By applying this program the score mean of student's problem-solving increased from 62% well up to 81%. In province of Quebec, Canada, when this program was first started, applying this program improved the students' math score when compared with the scores of other Canadian students in other parts. Furthermore, math mean score of Canadian students was higher than those of American peers in international mathematics exams (cited in Ferguson, 1995).

Celone (2001) tried to answer the question whether notional or conceptual teaching of chess can develop student's abstract thinking and their problem-solving ability or not. To answer this question he did a research on 19 students of elementary school who voluntarily participated in a one-week program that lasted 20 hours. Students were tested just before and after this program and by using equivalent forms of the TONI-3 Test of Non-Verbal Intelligence, a valid and reliable instrument associated with abstract reasoning and problem-solving and by using the Knight's Tour, a domain-specific instrument measuring overall chess problem-solving ability. The result of this study suggests that significant increase between scores just before and after the test was observed and the improvement was both in their problem-solving ability and intelligence quotient (IQ).

In another study done in New York on 3000 students in 100 public schools, the efficacy of chess programs on developing problem-solving ability and reading comprehension was observed (Margulies, 1993). The result of another study done by Ferguson (1995) shows that by including chess in the curriculum, math teachers could detect significantly improvement of math scores of students and their problem-solving power when compared with those students who had not taken part in these programs. Ferguson goes on to say that in 1989 only 120 students were enrolled and trained in chess clubs but in three years, that is, in 1992, the number of students in chess schools amounted to 19000. The increase was owing to appraising the results of relevant studies and convincing the families and educational personnel of usefulness and effectiveness of chess play and its pedagogical and social effects.

5. Conclusion

The results of the present study and other relevant researches in this area suggest that chess teaching to students at different educational levels, improves significantly their mathematical problem-solving ability. Furthermore, the result of this study suggests that chess play has the potential to increase meta-cognitive ability of the learners. As we already mentioned, no documented or compelling research has yet been done. in this regard. So, there is much room for interested researchers and scholars to do new similar studies with the hope that they may contribute to this field of study.

Pedagogical implications of the current study is directed to educational administers, educators, professors and all those who are interested in developing mathematics teaching and instruction. The question or suggestion is, "why should not we introduce chess teaching along with teaching of other subjects? Should we use chess as a useful educational tool, in improving math teaching or enhancing problem-solving strategies?" If we apply the above-mentioned suggestions, we hope to achieve the following objectives:

- The students would be able to think on problems reasonably and plausibly and would find the ability to analyze the problems correctly. In fact, they would learn the main framework and approaches of solving the problems.
- Enhancing perception, creativity and reasoning of the students by analysis and practice of different chess positions.
- When students experience the subtlety and sophistication of chess play, upon encountering complex and subtle matters, they often associate or link these two elements and discover the logic and subtlety of mathematics. In reality, this complexity may take tangible or real forms for students.
- Chess play enhances thinking and abstract thought.
- Chess play can create an impression or the sort of thinking in the students to the effect that they might not get disappointed or frustrated on facing a difficult problem. The students do their best to sort out the problem in an optimistic or persistent way.

In sum, we may claim that chess will create a **strong belief system** in the individuals as problem-solvers.

Acknowledgment

This paper has been selected from a research project, with the same title, in the Islamic Azad University, Ghorveh branch, Kurdistan, Iran. We are grateful to the Mr. Saman Saedi in Sanandaj who kindly helped us to collect data for this research.

References

Artzt, A., & Armour–Thomas, E. (1992). Development of a cognitive – meta-cognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction*, *9*, 137-175.

Brenda, D. (2003). *Chess, anyone? Chess as an essential teaching tool.* Retrieved May 18, 2004, from http://www.educationworld.com/a_curr/profdev031.shtml.

Brown, A. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 65-116). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Celone, J. (2001). The effects of a chess program on abstract reasoning and problem-solving in elementary school children. *Ann Arbor, MI. Bell & Howell Information and Learning Co*.

Dauvergne, P. (2000). *The case for chess as a tool to develop our children's minds*. Retrieved May 18, 2004, from www.uschess.org.

Ferguson, R. (1995). Chess in education research summary. *Paper presented at the Chess in Education "A Wise Move" Conference, New York, NY.*

Ferreira, D., & Palhares, P. (2008). Chess and problem solving involving patterns. *Montana Mathematics Enthusiast, 5*, 249-256.

Flavell, G. H. (1979). Metacognition and cognitive monitoring: A new area of psychological inquiry. *American Psychologist, 34*, 906-911.

Flavell, J. H. (1971). First discussant's comments: What is memory development the development of? *Human Development, 14,* 277-278.

Frank, A. (1974). *Chess and aptitudes*. Unpublished doctoral dissertation, LaSalle University, Mandeville, LA.

Gooya, Z. (1992). *Influences of meta-cognition-based teaching and teaching via problem solving on student's beliefs about mathematics and mathematical problem solving.* Unpublished doctoral dissertation, University of British Columbia, Columbia.

Hartman, H. J. (2001). Developing students' metacognitive knowledge and skills. In H. J. Hartman (Ed.), *Metacognition in Learning and Instruction: Theory, research and practice* (pp. 33-67). Boston: Kluwer Academic.

Horgan, D. (1988). *Where experts come from*. Paper presented at the Annual Meeting of the Decision Science Institute, Lincoln, NE.

Kazemi, F., Fadae, M. R., & Bayat, S. (2010). A subtle view to meta-cognitive aspect of mathematical problems solving. *Proceedings of the Social and Behavioral Sciences, 8*, 420–426.

Lester, F. K., Garofalo, J., & Krool, D. L. (1989). *The role of meta-cognition in mathematical problem solving: A study of two grade seven classes*. (Final report to the project of the National Science Foundation of NSF project MDR 85–50346). Bloomington: Indiana University, Mathematics Education Development Center.

Liptrap, J. (1997). Chess and standardized test scores. *Chess Coach Newsletter, 11*, 5-7.

Lucangli, D., & Cornoldi, C. (1997). Mathematics and metacognition: What is the nature of relationship? *Mathematical Cognition, 3*, 121-139.

Margulies, S. (1993). The effect of chess on reading scores: District nine chess program second year report. (Article No. 5) *United States Chess Federation Scholastic Department.*

Meyers, J. (2005). *Why offer chess in schools?* Retrieved August 5, 2005, from www.chess.about.com/library/weekly/aa05a08a.htm.

Milat, M. (1997). *The role of chess in modern education*. Retrieved on October, 2005, from http://www.chess.bc.ca/marcel2.html.

Panaoura, A., Philippou, G, I., & Christou, C. (2003). Young pupil's metacognitive ability in mathematics. *European Research in Mathematics Education, 3*, 1-9.

Pape, S. J., & Smith, C. (2002). Self-regulation mathematics skills, *Theory into Practice, 41,* 93-101.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Orlando, FL: Academic Press.

Stefurak, L. (2003). Why chess in elementary school education? Retrieved March, 2003, from http://www.misd.wednet.edu/IPWebPage/IPChess//why.html.

Thompson, M. (2003). Does the playing of chess lead to improved scholastic achievement? *Issues In Educational Research, 13,* 13-26.