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Original Article

EVALUATING THE COMPUTATIONAL CAPACITY OF STUDENTS IN CHESS CLASSES AFTER APPLYING TACTICAL COORDINATION EXERCISES

AVALIAÇÃO DA CAPACIDADE COMPUTACIONAL DE ALUNOS NAS AULAS DE XADREZ APÓS A APLICAÇÃO DE EXERCÍCIOS DE COORDENAÇÃO TÁTICA

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RESUMO
Através das etapas da pesquisa, 4 testes técnicos (Ataque Combinado; Xeque-mate em 2-4 Movimentos; Escolhendo a Solução Ótima; Estratégia) e 2 testes psicológicos (Landont Open Loop; Teste de Taping) foram identificados como meios para avaliar a eficácia da aplicação de exercícios de coordenação tática. Ao mesmo tempo, 17 grupos objetivos e viáveis de exercícios foram selecionados e aplicados por 4 meses para contribuir para melhorar a capacidade de cálculo dos alunos em aulas de xadrez na Universidade de Tecnologia e Educação da Cidade de Ho Chi Minh (HCMUTE). Os resultados mostraram que a taxa de crescimento após o experimento do grupo de controle através de testes individuais foi menor em 0,47% (Tapping) e maior em 17,97% (Ataque Combinado), a taxa média de crescimento foi de 10,55%. Enquanto isso, exceto para o teste de Tapping, a taxa de crescimento dos 5 testes restantes do grupo experimental aumentou significativamente em comparação com o grupo de controle. Especificamente, a taxa de crescimento dos testes individuais do grupo experimental foi a mais baixa, de 2,31% (Tapping), e a mais alta, de 40,78% (Combinação), com uma taxa média de crescimento de 25,84%. Isso demonstra a correção, a racionalidade e a eficácia dos grupos de exercícios de coordenação tática selecionados para inclusão no currículo de xadrez da HCMUTE.
Palavras-chave: aplicação, avaliação, cálculo, capacidade, xadrez, coordenação, exercícios, estratégia, aluno.

ABSTRACT
Through the research steps, 4 technical tests (Combined Attack; Checkmate in 2-4 Moves; Choosing the Optimal Solution; Strategy) and 2 psychological tests (Landont Open Loop; Taping Test) were identified as means to evaluate the effectiveness of applying tactical coordination exercises. At the same time, 17 objective and feasible groups of exercises were selected and applied for 4 months to contribute to improving the calculation ability of students in chess classes at Ho Chi Minh City University of Technology and Education (HCMUTE). The results showed that the growth rate after the experiment of the control group through individual tests was lowest at 0.47% (Tapping) and highest at 17.97% (Combined Attack), the average growth rate was 10.55%. Meanwhile, except for the Tapping test, the growth rate of the remaining 5 tests of the experiment group all increased significantly compared to the control group. Specifically, the growth rate of the individual tests of the experimental group was lowest at 2.31% (Tapping), and highest at 40.78% (Combination), the average growth rate reached 25.84%. This shows the correctness, rationality and effectiveness of the tactical coordination exercise groups selected to be included in the chess curriculum at HCMUTE.
Keywords: application, assessment, calculation, capacity, chess, coordination, exercises, strategy, student.

Introduction

Chess is an intellectual sport, containing very interesting mysteries, so it has attracted millions of people around the world to play every day. According to statistics from the Olympic Chess Committee, there are currently more than 700 million people (about 8.6% of the world's population) playing chess; More than 2 million players compete in international tournaments. The number of chess players in the US is more than 40 million people, 6 million people in the UK, 16 million people in Germany, more than 50% of the population in Russia, and 70% of the population in India (more than 85 million people). More than half of them are between the ages of 18-34[1] [1].

According to the famous online chess site - Chessfox, to teach and train methodically, it is necessary to ensure comprehensive 7 skills: Tactics - Strategy - Calculation - Opening - Endgame - Evaluation – Imagination[2]. This shows that calculation is one of the important skills.

In the 21st century, computational thinking has been affirmed as one of the particularly important abilities[3].

Unlike other sports, chess requires little physical strength but requires quite a lot of psychological ability, intelligence, ability to analyze and evaluate situations. Continuously changing situations require players to have specialized knowledge and the ability to calculate quickly in each specific case.

The Chessfox site has outlined four important elements of effective calculation techniques in chess, which are: (1) Always start your calculation by keeping track of your opponent's final move intentions.; (2) Must understand the difference between forced moves and unbound moves (3) Chess tactical skills will effectively support calculation skills; (4) The ability to calculate deeper variables depends greatly on the player's imagination[4].

It can be seen that calculating plans is one of the factors that contain chess talent. To develop computational ability in chess, it is necessary to solve many exercises on coordination, positions.... without moving pieces on the chessboard[5]. At the same time, Chess is an effective and powerful means of developing children's problem-solving abilities in the field of mathematics[6]. Several studies have shown that chess players (including both adults and children) are smarter than those or non-chess players[7, 2, 8.]

Therefore, studying chess players' calculations is very complicated. To study the computational capacity of chess players, it is necessary to develop appropriate research methods and tasks[9].

Currently, the known information about chess players' thinking has been mentioned in the research works of chess Grandmasters, psychologists, psychophysicists, cyberneticians... Chess players have used them as a model to study thinking. Attention to appropriate research methods has been used in the work of various authors. In 1894, the book by famous psychologist - Bine titled "The Computational Psychology of Chess Players" was published in Paris. The results of this research work are of great significance because it is not only the first work on chess calculations but also a work written by a great psychological scientist. This work has drawn valuable conclusions about the psychological processes of chess players' thinking that take place in blind chess matches. Through experiments, it has been shown that during the time chess Grandmasters played fantasy chess (according to the rule of not using the entire chessboard of pieces), Bine discovered something interesting. That is, he understood the entire task of studying complex thinking as well as trying to visualize all the events that happen in the chess player's mind while playing chess. He wrote: “If we could look into the head of a chess player, we would see there a whole world of images, ideas, emotions and fears, endlessly vibrant states of consciousness... If we compare all the above factors, we will, with the utmost caution, draw a rough diagram. Through this, Bine came to the conclusion that with the help of chess, it is possible to study different psychological processes. At the same time, chess opens up the possibility of studying creative activities and similar important issues, such as the relationship between memory and logical thinking[9].

Thus, it can be seen that the process of calculating variations in games is very important for chess players and is the deciding factor in the success or failure of the game plan in the game. Once the calculation is wrong or the calculation time is too long, chess situations lead to unfortunate results such as winning becoming a draw, drawing becoming losing or winning becoming losing. That is the root cause of superficiality or shallowness in thinking and calculation, which has a long-term impact on the chess player's level. Thereby, research on computing capacity in general, on methods and means to develop computing capacity as well as how to evaluate the computing capacity of chess players is of great interest to foreign scientists and experts [7, 8, 9].

On the other hand, according to experts' point of view, computing ability is one of the factors that determine chess players's competition results and sports achievements. In recent years, research to determine the nature and mechanism of chess players' calculation process has always attracted the attention of scientists. Exploring the computational mechanisms that appear in the field of chess (games) to understand why players choose one move over another? Why do they make this or that mistake?... This has great significance both theoretically and practically in chess. From there, it is necessary to have appropriate measures to increase the effectiveness of the teaching and training process and the enjoyment of chess students. In particular, it is important to focus on developing tactical coordination skills in a methodical and scientific basis [2, 5, 7].

Through a preliminary assessment of the current status of chess teaching at HCMUTE, we find that the use of methods and means to form and develop students' computing capacity is not really considered. This has had a significant impact on learners' love, interest, progress and learning outcomes. Specifically, students lack acumen and depth in calculation and problem solving, especially when encountering complex situations or limited thinking time. Based on the above reason, we find that it is necessary to conduct an assessment of students's computational capacity in HCMUTE chess classes. The research results will be a useful reference for chess instructors in adjusting their professional teaching process.

Methods

Sample

Subjects to be interviewed: 20 people including lecturers and physical education trainers with knowledge of chess expertise at a number of universities in Ho Chi Minh City (Vietnam) with academic degrees including: 03 PhDs (accounting for 15%); 17 Masters (accounting for 85%), and working seniority: <3 years (reaching a rate of 5%); 3-5 years (reaching 20%); 6-10 years (rate 50%); >10 years (25%). Among these, there are 6 lecteures who are teaching chess at Ho Chi Minh City University of Technology and Education. These 20 people (interview subjects) play an important role and are responsible for selecting application exercises as well as tests used to evaluate computing capacity in HCMUTE's chess classes.

Subjects for testing and pedagogical experimentation: 66 male students, aged of 19 - 22, participating in 2 chess classes at HCMUTE. This subject belongs to 2 separate chess classes and is divided into 2 groups: Control group (32 students belongs to Classes 1) and Experimental group (34 students belongs to Classes 2).

Scope of research: Assessing the computational capacity of students in chess classes.

Procedures

The research was conducted in classrooms and lecture halls for teaching and learning chess at HCMUTE. The distribution and collection of student opinion surveys are conducted in physical education classes.

The pedagogical experimental method is prioritized for use to evaluate students's computational capacity belong to two experimental and control groups of HCMUTE chess classes after applying the system of selected exercises. From there, it is possible to give accurate and objective results about the outstanding and outstanding effectiveness of those exercises in teaching practice.

The experimental subjects were conducted on both groups of subjects: male students of 2 chess classes from 19 - 22 years old of HCMUTE. Among them, the Control group includes 32 male students (belongs to Classes 1) studying according to HCMUTE's current chess program. The program is 15 weeks, 2 sessions per week, 5 periods per session (250 minutes). The content of the chess program has been standardized and approved by the Training Department and HCMUTE Board of Directors. It includes knowledge about the history of chess; rule; flag ends; position; coordinated moves in the opening phase; the middle game of a chess game; some fields related to chess. The experimental group, including 34 male students (belongs to Classes 2) also studied according to HCMUTE's current chess program, including 15 weeks, 2 lessons per week, 5 periods (150 minutes) per lesson. But the experimental group has the application of selected tactical exercises.

In each lesson, students in the experimental group practice one type of exercise for 30 minutes. Specifically, the experimental process of applying the exercises is presented in Table 1.

The selection of control group and experimental group according to chess class 1 and chess class 2 was done by purposive method. The experimental period is conducted for one semester - 4 months (from September 2023 to January 2024).

Table 1. Experimental progress of applying tactical coordination exercises

Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Content	Basic knowledge			Chess Rules			Opening					Mid-game					Mid-game							Endgame			Chess position			
Applying the exercise to the Experimental Group												Ex.1	Ex.2	Ex.3	Ex.4	**Midterm Test**	Ex.5	Ex.6	Ex.7	Ex.8	Ex.9	Ex.10	Ex.11							**Final exam**

Source: Authors.

Statistical analysis

Common methods used in the process of carrying out research tasks include Synthesizing and analyzing the methodology of related documents; Sociological Investigation; Pedagogical examination; Test psychological and physiological functions; Statistics and calculations.

Collecting and selecting relevant documents from scientists, chess teaching materials, textbooks, a number of magazines inside and outside the industry, and a collection of scientific research works to synthesis of exercises to evaluate the calculation speed of students learning chess.

Then, interviewing experts to choose popular and appropriate exercises. Next is to check the reliability of the tests (the degree of agreement between the results of tests on the same subject and under the same experimental conditions).

In this study, determining the reliability of 11 tests (7 technical tests and 4 psychological tests) was conducted using the Retest method. That is, determine the reliability coefficient between the results of two tests at the same time, conditions, and subjects. Specifically, statistic the results achieved in the first and second tests (retest) and then calculate the rtt value. If $r_{tt} \geq 0.8$, the test is reliable enough.

On the contrary, tests with $r_{tt} < 0.8$ are eliminated. Finally, check the informability of the tests (the level of accuracy of the test in measuring to determine a certain characteristic, such as quality, ability, characteristic...).

In this study, the informativeness of the tests is shown through the correlation coefficient between the results of performing the tests and the competition results (total marks achieved in the tournament) at the rapid chess tournament (15 minutes/game) in classes in the form of competition according to the Swiss system. Requires tests to have rtc≥ 0.6; if rtc < 0.6, they will be eliminated.

SPSS 22.0 software was also used to process data and evaluate the development of students's computational capacity in the experimental and control groups after applying selected exercises to the practice of teaching chess.

Specifically, the Student t-test used for two independent samples ($n \geq 30$) and two related samples ($n \geq 30$), along with calculating the correlation coefficient to determine the reporting and reliability of the selected tests.

Results

Selecting tests to evaluate the computational ability of students in chess classes

Take the following 3 steps to ensure reasonable and objective calculations:

Synthesizing and systematizing exercises to evaluate chess students' computational capacity. Through consulting and analyzing relevant professional documents, the study has synthesized 25 groups of calculation exercises for chess students at HCMUTE.

Eliminate less popular and rarely used exercise groups. Based on the general exercises and selection principles, the topic has omitted complex and rarely used exercises. As a result, 20 groups of exercises remain to be included in the next interview step.

Through interviews with experts, identify groups of exercises to improve computational capacity in chess.

The convention is to only select exercises that evaluate chess students' computational abilities with a rate of ≥80% approval through 2 interviews (eliminate exercises with an approval rate <80%). At the same time, there must be consistency (no significant differences) between the two interviews.

Synthesizing and systematizing exercises to evaluate the computational capacity of students in chess classes

Accordingly, the study has compiled 23 tests (14 chess expertise tests and 9 psychological tests) to help evaluate students' computing ability as follows. Chess expertise tests include: (1) Analysing, evaluating and planning; (2) Analyzing thoughts into words; (3) Combination attack; (4) Chess position checkmate after 2-4 moves; (5) Calculating according to formula (single branch, multiple branch, complex branch); (6) Selecting the optimal solution; (7) Tests of tactics to attack the King; (8) Strong squares, weak squares; (9) Exploitating of open columns, diagonals (10) Pawn structure; (11) Endgame; (12) Arrangement of troops; (13) Space and center; (14) Strategy.

Psychological tests include: (1) Landont open loop; (2) Remembering the chess position; (3) Arithmetic addition and subtraction; (4) Raven Test; (5) Taping Test; (6) Arithmetic correlation; (7) 40 points on a circle; (8) Visual memory; (9) Sensing of time.

Preliminary pruning of less popular tests

On the basis of systematized tests, the research has reduced but less common tests and only retained feasible tests, suitable for chess teaching conditions at HCMUTE. Results from the initial 23 synthetic tests, only 15 tests remained to be included in the expert interviews.

Chess expertise tests include: (1) Analysing, evaluating and planning; (2) Combination attack; (3) Strong squares, weak squares; (4) The chess position checkmate after 2-4 moves; (5) Tests of tactics to attack the King; (6) Selecting the optimal solution; (7) Exploitating of open columns diagonals; (8) Endgame; (9) Strategy.

Psychological tests include: (1) Landont open loop; (2) Remembering the chess position; (3) Arithmetic addition and subtraction; (4) Raven Test; (5) Taping Test; (6) Arithmetic correlation.

Interview using questionnaires to get expert opinions

From the above results, we have conducted interviews with coaches and PE lecturers who understand chess to identify tests to evaluate the effectiveness of groups of computational ability exercises in an objective way, ensuring reliability and notification.

Conducting indirect interviews using questionnaires (the number of questionnaires sent out is 20, the number of questionnaires received is 20).

Each test in the interview panel has 5 levels of options (according to the Likert scale) to answer: Completely agree: (5 marks); Agree: (4 marks); Normal: (3 marks); Disagree: (2 marks); Strongly disagree: (1 mark)

The convention is to only select tests to evaluate the computational ability of chess students that have a rate of ≥80% approval through 2 interviews (remove exercises with an approval rate <80%), and there must be consistency between the two interviews.

The results presented in table 2 show:

There are 7/9 professional tests with ≥80% approval rate. At the same time, we have conducted the Wilcoxon signed rank test, noting that all 9/9 selection interview expertise tests had Sig>0.05. Thereby, it proves that there is no statistically significant difference in opinions between the two interviews.

Similarly, 2/6 psychological tests had a rate of ≥80% approval. Conducting the Wilcoxon signed rank test also recorded: all 6/6 selection interview psychological tests had Sig>0.05. Thereby, it shows that there is no statistically significant difference in opinions between the two interviews.

Thus, from 15 tests, through expert opinions, 11 tests were selected that met the conventional conditions [7 professional tests include: (1) Analysing, evaluating - planning; (2) Combination attack; (3) The chess position checkmate after 2-4 moves; (4) Tests of tactics to attack the King; (5) Selecting the optimal solution; (6) Endgame; (7) Strategy, and 4 psychological tests including: (1) Landont open loop; (2) Raven Test; (3) Taping Test; (4) Arithmetic correlation].

Table 2. Results of consulting experts to select tests to evaluate the effectiveness of applying groups of tactical coordination exercises to help improve calculation capacity for students in chess classes

No	**Test**	**1st time (n=20)**		**2nd time (n=20)**		**Test Statistics[a]**	
		Σ mark	**%**	**Σ mark**	**%**	**Z**	**Asymp. Sig. (2-tailed)**
	Chess expertise tests						
1	Analysing, evaluating - planning	49	82	48	80	-.447[b]	**.655**
2	Combination attack	53	88	51	85	-.816[b]	**.414**
3	Strong squares, weak squares	**28**	**47**	**26**	**43**	**-1.000[b]**	**.317**
4	Chess position checkmate after 2-4 moves	55	92	52	87	-1.134[b]	**.257**
5	Tests of tactics to attack the King	48	80	49	82	-.447[c]	**.655**
6	Selecting the optimal solution	55	92	56	93	-.577[c]	**.564**
7	Exploitating of open columns, diagonals	**24**	**40**	**25**	**42**	**-.577[c]**	**.564**
8	Endgame	48	80	51	85	-1.342[c]	**.180**
9	Strategy	55	92	54	90	-.577[b]	**.564**
	Psychological tests						
1	Landont open loop	55	92	57	95	-1.414b	**0.157**
2	Remembering the chess position	**27**	**45**	**26**	**43**	**-.577c**	**0.564**
3	Arithmetic addition and subtraction	**27**	**45**	**27**	**45**	**.000d**	**1**
4	Raven Test	51	85	48	80	-1.342c	**0.18**
5	Taping Test	54	90	55	92	-.577b	**0.564**
6	Arithmetic correlation	51	85	51	85	.000d	**1**
(a. L2 < L1, b. L2 > L1, c. L2 = L1)							

Source: Authors

Checking the reliability and reporting of the selected tests

The results of determining the reliability and reporting of the test on the research subjects are presented in table 3.

Table 3. Reliability and reportability of selected tests on research subjects (n = 20)

No	Test	**R** (Pearson Correlation)	
		r_{tt}	r_{tc}
Chess expertise tests			
1	Analysing, evaluating - planning	0.57	0.21
2	Combination attack	**0.90**	**0.87**
3	Tests of tactics to attack the King	0.19	0-.12
4	Chess position checkmate after 2-4 moves	**0.85**	**0.86**
5	Selecting the optimal solution	**0.98**	**0.85**
6	Strategy	**0.95**	**0.94**
7	Endgame	0.58	0-.07
Psychological tests			
1	Raven Test	0.58	0.05
2	Landont open loop	**0.90**	**0.93**
3	Arithmetic correlation	0.30	0.30
4	Taping Test	**0.93**	**0.72**

Source: Authors

From the results of Table 3, we have finally selected 6 tests to ensure reliability and reporting on the research subjects. Those are 4 professional tests [Combination attack (mark); The chess position checkmate after 2-4 moves (mark); Selecting the optimal solution (mark); Strategy (mark)] and 2 psychological tests [(Landont open loop (bit/s); Taping Test (number of points).

Selecting and applying some types of tactical coordination exercises to help improve calculation capacity for students in HCMUTE chess classes

To ensure that the selected exercises are reasonable and objective, we carry out the following 3 steps:

Step 1. Synthesize and systematize exercises to improve chess students's computational capacity that have been used by domestic and foreign authors. Through consulting and analyzing relevant professional documents, the project has synthesized 25 groups of calculation speed exercises for chess students at HCMUTE.

Step 2. Based on the general exercises and selection principles, the topic has omitted complex and rarely used exercises. As a result, 20 groups of exercises remain to be included in the next interview step.

Step 3. Interview using questionnaires to get expert opinions (chess lecturers and coaches) to identify exercises to improve computational ability in chess for students in an objective and feasible way. Through interviews with experts, identify groups of exercises to improve computational capacity in chess. The convention is to only select exercises to evaluate the computational ability of chess students that have a rate of ≥80% approval through 2 interviews (remove exercises with an approval rate <80%), and at the same time There must be consistency (no significant differences) between the two interviews. As a result, 11 exercises were selected including: (1) Misleading; (2) Attraction; (3) Double attack; (4) Double check; (5) Openning the way; (6) Interference; (7) Promotion; (8) Liberation (box/line); (9) Strangulation; (10) Mill blow; (11) Seeking draw.

These exercises are put into experimental applications for subjects (control group - 32 students and experimental group - 34 students). Time and characteristics of participating groups are described in section Methods.

Evaluating the computational ability of students in chess classes after applying tactical coordination exercises

To use the t-stusent test validly, the following conditions must be satisfied: (1) Continuous data; (2) Normally distributed data; (3) Independence of observations; (4) Homogeneity of variance.

Conduct the Shapiro-Wilk test to check the level of conformity between the data distribution and the normal distribution. The results of the tests to assess the computational ability of students in the experimental and control groups all have P > 0.05, not rejecting the null hypothesis → it can be considered that the data has a normal distribution. This is the necessary basis to continue conducting the t-student test (use parametric testing).

Evaluating the computational ability of students in the chess control group before and after applying tactical coordination exercises

Conducting a hypothesis test about the average value of two dependent populations or paired combinations (Paired-Samples T-test). The test results before and after the experimental period are presented in Table 4. It showed that, although only applying the normal chess curriculum, chess students' computational ability belongs to the control group also had many positive changes after the experimental period. Specifically, 5/6 tests had a statistically significant difference after the experimental period.

Table 4. Evaluation of the Computational Ability of Students in the Chess Control Group after Applying Tactical Coordination Exercises

No	**Tests**	**Before the experiment (n=34)**		**After the experiment (n=32)**		**d $/\overline{X}_2 - \overline{X}_1/$**	**Comparation**		**W%**
		$\overline{X}_1$	$\pm S_A$	$\overline{X}_2$	$\pm S_B$		**t**	**P**	
1	Combination attack (mark)	**3.95**	0.94	**4.73**	0.88	0.78	9.32	<0.05	17.97
2	Chess position checkmate after 2-4 moves (mark)	**4.07**	0.93	**4.73**	0.88	0.65	8.28	<0.05	15
3	Selecting the optimal solution (mark)	**4.25**	0.78	**5.01**	0.81	0.76	12.9	<0.05	16.41
4	Strategy (mark)	**4.12**	0.47	**4.57**	0.77	0.45	4.14	<0.05	10.36
5	Landont open loop (bit/s)	**1.27**	0.03	**1.31**	0.04	0.03	6.82	<0.05	3.1
6	Tapping Test (number of points)	**126.8**	2.58	**127.4**	2.93	0.52	1.66	**>0.05**	0.47

Source: Authors

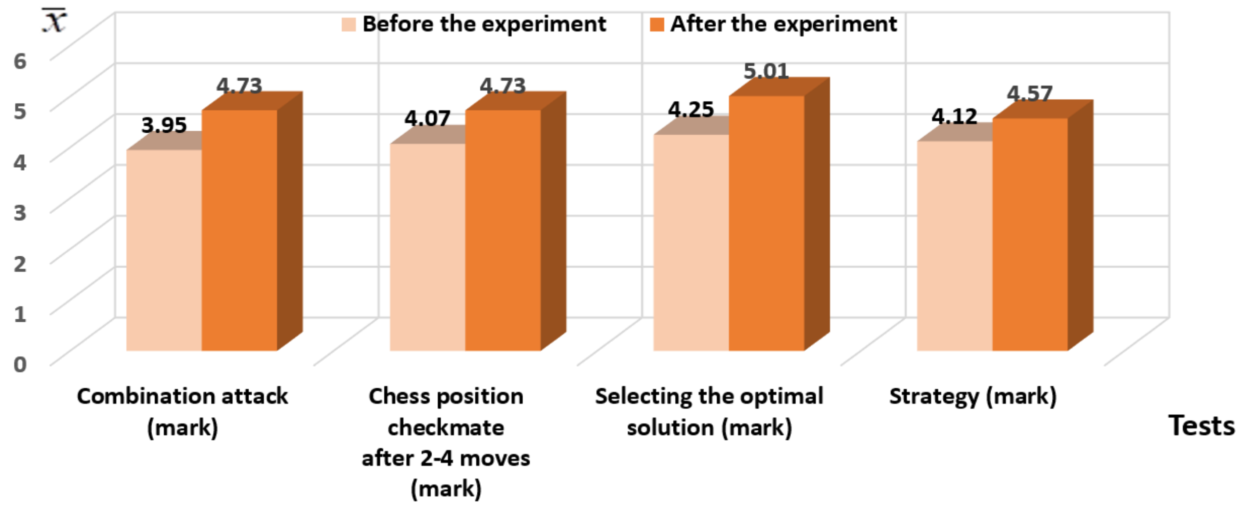

Figure 1. Comparison of professional tests of students in the chess control group before and after applying tactical coordination exercises
Source: Authors

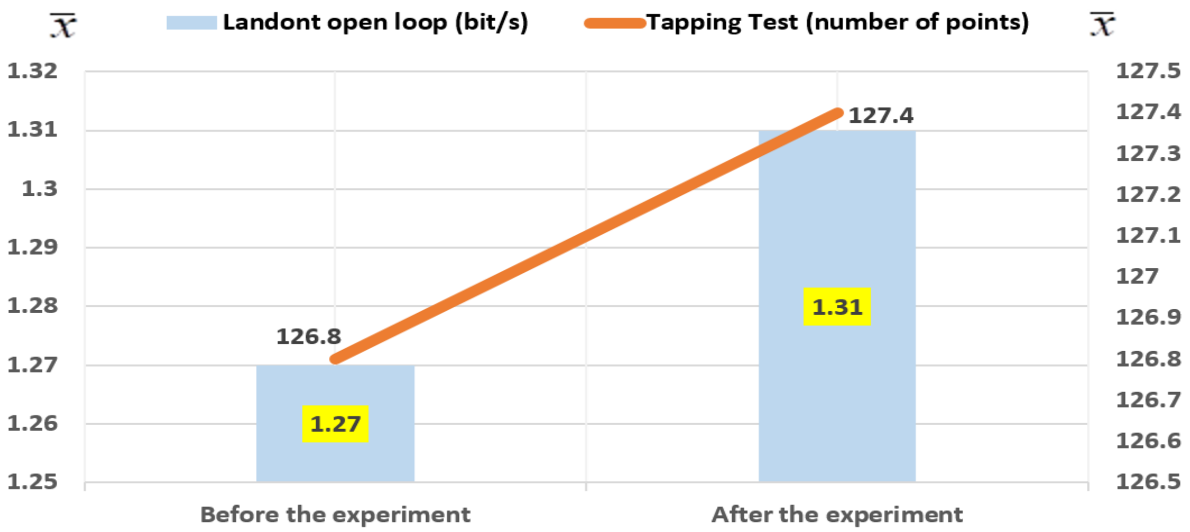

Figure 2. Comparison of psychological tests of students in the chess control group before and after applying tactical coordination exercises
Source: Authors

Specifically, the average values of the professional and psychological tests increased compared to before the experiment at the probability threshold P <0.05. This is further demonstrated in Figures 1 and 2.

Evaluating the computational ability of students in the chess experimental group before and after applying tactical coordination exercises

Similarly, when testing the hypothesis about the mean value of two dependent or paired populations (Paired-Samples T-test), the test results before and after the experiment are presented in table 5. After applying selected exercises, the computational ability of chess students in the experimental group has developed very well with 5/6 tests testing the average value having a statistically significant difference after the experimental period (with P<0.05). The results are even more transparent in Figure 3 and Figure 4.

Table 5. Evaluation of the Computational Ability of Students in the Chess Experimental Group after Applying Tactical Coordination Exercises

No	Test	Before the experiment (n=34)		After the experiment (n=32)		d $/\overline{X}_2 - \overline{X}_1/$	Comparation		W%
		$\overline{X}_1$	±SA	$\overline{X}_2$	±SB		t	P	
1	Combination attack (mark)	**4.10**	1.05	**6.20**	1.09	2.10	25.91	<0.05	40.78
2	Chess position checkmate after 2-4 moves (mark)	**4.06**	0.82	**5.82**	0.73	1.76	26.18	<0.05	35.63
3	Selecting the optimal solution (mark)	**4.11**	0.71	**5.85**	0.68	1.73	20.40	<0.05	34.94
4	Strategy (mark)	**4.33**	0.92	**5.92**	0.78	1.58	23.25	<0.05	31.02
5	Landont open loop (bit/s)	**1.28**	0.03	**1.42**	0.05	0.14	20.61	<0.05	10.37
6	Tapping Test (number of points)	**128.6**	10.13	**131.6**	3.30	2.97	1.71	**>0.05**	2.31

Source: Authors

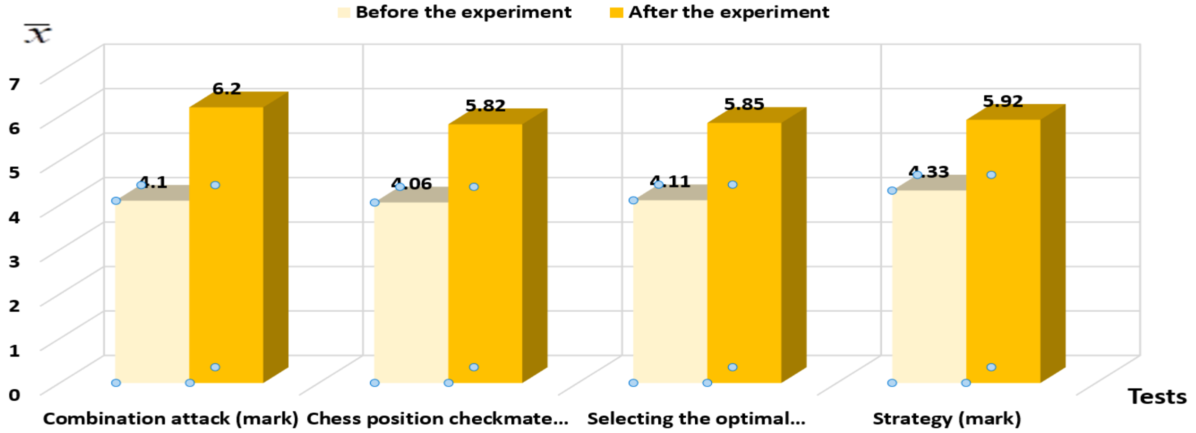

Figure 3. Comparison of professional tests of students in the chess experimental group before and after applying tactical coordination exercises
Source: Authors

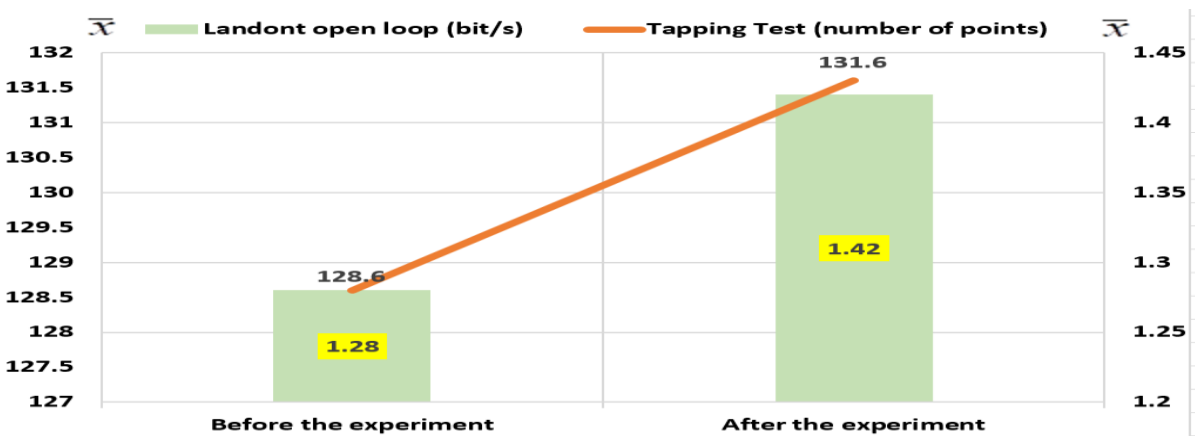

Figure 4. Comparison of psychological tests of students in the chess experimental group before and after applying tactical coordination exercises
Source: Authors

Comparing the computational capacity of students in two control and experimental groups in chess classes before and after applying tactical coordination exercises

The question is whether the starting point of this capacity of these two groups (before the experiment) is similar or not? And after the experimental period, which group has the superiority and to what extent?

From the test results presented in Table 6, it is reflected that, before the experiment, the overall average value of 6 tests of 2 groups (4 professional tests) and (2 psychological function tests) of the experimental group and the Control group were not significantly different (Sig > 0.05). This shows that there is no difference in computing ability when starting to participate in chess classes between groups of students before the experiment. The research results presented in Table 7, Figures 5 and 6 show that, after the experimental period, 4/4 of the experimental group's professional tests were superior to the control group’s. The difference in mean value is statistically significant with P<0.05. Meanwhile, after the experiment, the experimental group's psychological tests also increased higher than the control group's. The difference in mean value is statistically significant (P<0.05).

Table 4 shows that after the experimental period, the control group's growth rate through individual tests was lowest at 0.47% (Tapping) and highest at 17.97% (Combination attack). The average growth rate reached 10.55%. Meanwhile, table 5 reflects that after the experimental period, the experimental group's computing capacity increased dramatically in a positive direction. Specifically, the post-trial growth rate of individual tests was lowest at 2.31% (Tapping Test), while the highest reached 40.78% (Combined Attack). The average growth rate reaches 25.84%.

Thus, except for the Tapping test, the experimental group's the growth rate of the remaining 5 tests increased significantly compared to the control group's. This is clearly shown in chart 7.

Table 6. Calculation Ability of Students in Two Control and Experimental Groups of Chess Classes before Applying Tactical Coordination Exercises

Test	Group	Levene's Test for Equality of Variances			$\overline{X}$ (Mean)	± SD (Std. Deviation)	d $/\overline{X}_{tn} - \overline{X}_{dc}/$	t	Sig. (2-tailed)
		N	F	Sig.					
Combination attack (mark)	Ctrl	32	1.027	.315	**3.95**	0.94	0.15	.608	**.545**
	Epel	34			**4.10**	1.05			
Chess position checkmate after 2-4 moves (mark)	Ctrl	32	.002	.965	**4.07**	0.93	0.04	.076	**.940**
	Epel	34			**4.11**	0.82			
Selecting the optimal solution (mark)	Ctrl	32	1.140	.290	**4.25**	0.78	0.14	716	**.476**
	Epel	34			**4.11**	0.71			
Strategy (mark)	Ctrl	32	15.429	.000	**4.12**	0.47	0.21	1.180	**.243**
	Epel	34			**4.33**	0.92			
Landont open loop (bit/s)	Ctrl	32	.788	.378	**1.27**	0.03	0.01	.467	**.642**
	Epel	34			**1.28**	0.03			
Tapping Test (number of points)	Ctrl	32	1.315	.256	**126.8**	2.58	1.8	.948	**.346**
	Epel	34			**128.6**	10.13			

Ctrl: Control
Epel: Experimental
Source: Authors

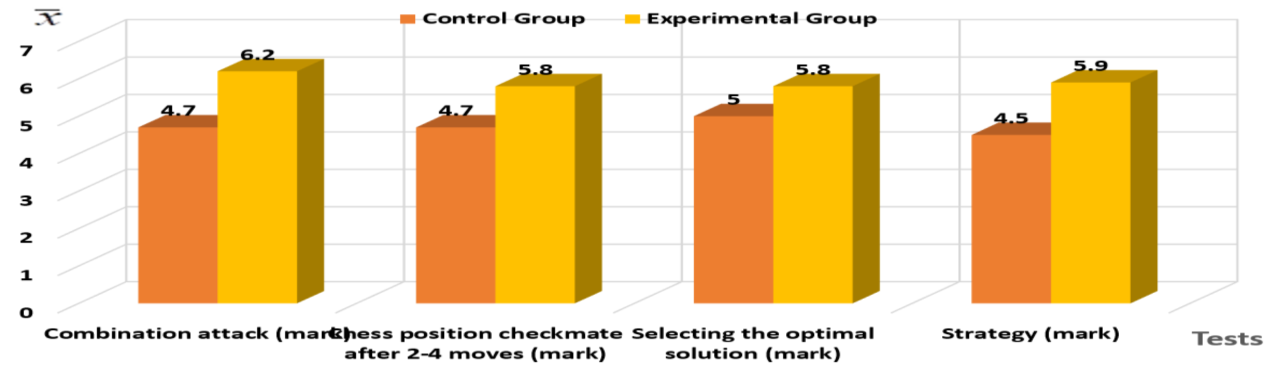

Figure 5. Comparison of expertise tests of students in the experimental and control groups after applying tactical coordination exercises

Source: Authors

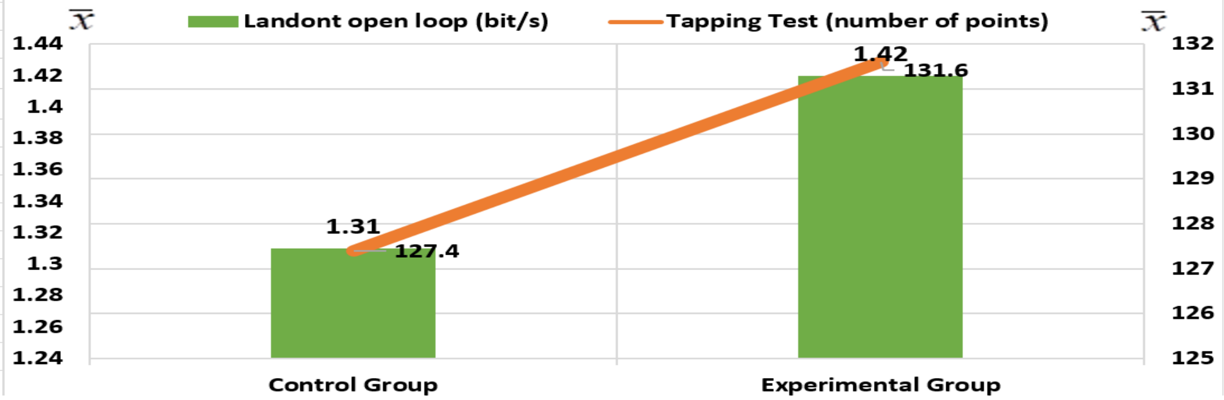

Figure 6. Comparison of psychological tests of students in the experimental and control groups after applying strategic coordination exercises

Source: Authors

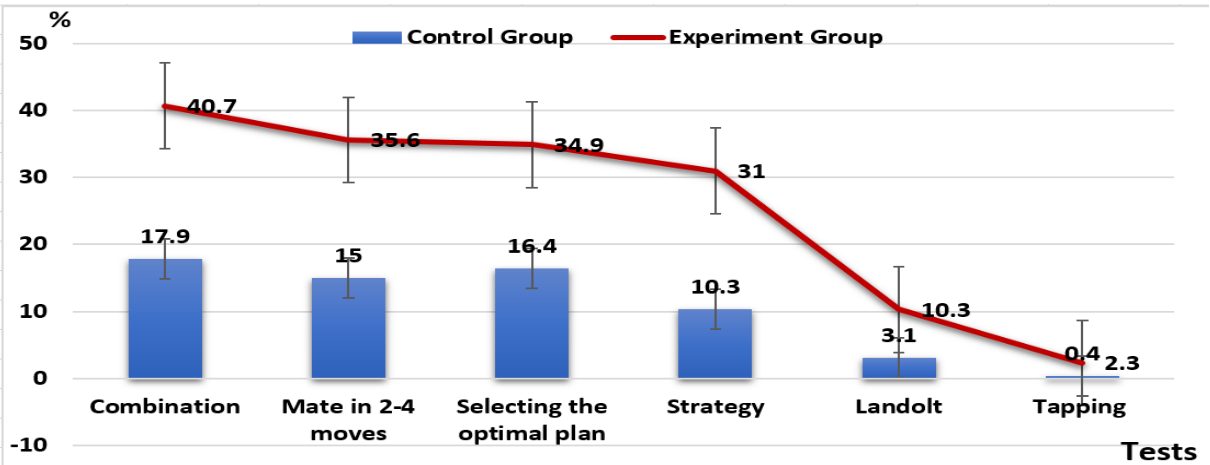

Figure 7. Comparison of the growth rate of professional and psychological tests of students in the experimental and control groups before and after applying strategic coordination exercises

Source: Authors

Table 7. Calculation Ability of Students in Two Control and Experimental Groups of Chess Classes after Applying Tactical Coordination Exercises

Test	Group	Levene's Test for Equality of Variances			$\overline{X}$ (Mean)	± SD (Std. Deviation)	d $/\overline{X}_{tn} - \overline{X}_{dc}/$	t	Sig. (2-tailed)
		N	F	Sig.					
	Ctrl	32	2.11	.15	**4.73**	0.88	1.47	5.972	**.000**

Combination attack (mark)	Epel	34			**6.20**	1.09			
Chess position checkmate after 2-4 moves (mark)	Ctrl	32	1.14	.28	**4.73**	0.88	1.09	5.431	**.000**
	Epel	34			**5.82**	0.73			
Selecting the optimal solution (mark)	Ctrl	32	1.37	.24	**5.01**	0.81	0.84	4.532	**.000**
	Epel	34			**5.85**	0.68			
Strategy (mark)	Ctrl	32	.17	.67	**4.57**	0.77	1.35	7.002	**.000**
	Epel	34			**5.92**	0.78			
Landont open loop (bit/s)	Ctrl	32	.56	.45	**1.31**	0.04	0.11	9.420	**.000**
	Epel	34			**1.42**	0.05			
Tapping Test (number of points)	Ctrl	32	.53	.46	**127.4**	2.93	4.2	5.438	**.000**
	Epel	34			**131.6**	3.30			

Ctrl: Control
Epel: Experimental
Source: Authors

Discussion

There have been quite a few foreign works related to computational capacity in chess: In the 21st century, computational thinking is one of the indispensable skills for humans[10]. Students will easily master the skills involved in solving many problems when they are enabled to develop their computational thinking[11]. Furthermore, Ching et al demonstrated that some board games are specifically designed to be suitable for developing computational thinking in their participants[12]. A study by Tsarava et al. also showed high support for including board games in the training process as an introductory activity to enhance learners' computational thinking[13]. While another study mentioned that incorporating board games into daily activities in libraries is essential[14]. Other well-designed and elaborate studies have demonstrated the development of learners' computational thinking through board games. This shows that there is a wide-open opportunity for all lecturers if they want to engage learners in computational thinking through interesting but no less complex activities from playing chess[15].

According to Bell e Vahrenhold, non-associative activities began to gain attention after being introduced into the curriculum reform in some countries. Accordingly, we can see an increase in the number of research works using chess to promote players' computational thinking skills[16].

Reality shows that chess players who can play with many players at the same time without looking at the board must have a special memory. There is a close relationship between chess calculation and perception, memory and attention span[9]. Research results of experts such as Grandmasters I. Zenevxki, A. Kotov, Kgogius recorded from analyzing the thinking process of chess players when making mistakes in the game. It has been found that violating memory operations will cause computational "inertia". During the thinking (calculation) process, a certain piece was "forgotten", resulting in an error in the calculation[5].

Groot's research has confirmed: Perception and memory are more important discriminators of chess proficiency than the ability to foresight when choosing moves in chess[17]. Athletes of different classes and levels have different chess calculation abilities; Through research on the creative calculation capacity of chess players, it has been shown that the calculation capacity of chess players develops in a spiral pattern[5].

Guid and Bratko through the study “Search-based estimation of problem difficulty for humans” proposed an algorithm to estimate the difficulty of chess positions in regular chess games[18]. A study by Işıkgöz, E. "Analysis on math success of secondary school students playing and not playing chess (Sakarya province sample)" stated that: There is a significant difference between students' end-of-year scores compared to their scores. However, there is no significant difference between the end-of-year scores of chess-playing students according to gender and grade level[19]. Even the most powerful computers in the world are not capable of evaluating every possible move in chess games"[20]. Frydman, M., & Lynn, R. suggested that high levels of spatial, working memory, and other cognitive abilities are necessary for high performance in chess training and competition[21].

Andrade and colleagues have argued that: Computational modeling has helped researchers in various fields of knowledge and chess, and it can be an invaluable aid for research in cognitive science[22]. For the AI community, the work shows that even extremely advanced versions of weak AI cannot perform better than humans in all cases[23]. By combining Centiprise, Q-learning and Neural Networks evaluation, the study achieved a comprehensive analysis of the dynamics of the game and improved the ability to evaluate strategic moves and suggest decisions. The study also contributed to the further development of intelligent and complex chess AI systems, providing a deeper understanding of the immense complexity of the game[24]. William M. Bart's research has provided evidence that chess practice has beneficial effects on cognition and education among school-age students[25]. One can also observe another study that proposed using robots as an interesting supporting activity for the use of board games[16].

Some literature on intelligence suggests that chess players have higher IQs than the general non-chess playing population. But surprisingly, it does not provide any evidence that adult chess players have better visuospatial skills (while some evidence of higher visuospatial skills in children has been found)[26].

Conclusion

The research results have selected 6 tests which ensure reliability and information on the research subjects, which are 4 professional tests (Combination attack; Chess position checkmate after 2-4 moves; Choosing options optimization; Strategy) and 2 psychological tests (Landont open loop; Taping Test) as a means to evaluate the effectiveness of applying selected tactical coordination exercises.

After applying 11 types of tactical coordination exercises (include Misleading; Attraction; Double attack; Double check; Openning the way; Interference; Promotion; Liberation (box/line); Strangulation; Mill blow; Seeking draw), the results of the tests in the experimental group and control group both increased, but the growth of the experimental group was significantly superior to that of the control group (with $P<0.05$). Specifically, all 6/6 tests had t-calculus greater than t-table with $P<0.05$. This confirms the effectiveness and usability of tactical coordination exercise groups when included in chess curriculum after a 4-month trial period.

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