DEVELOPING CRITICAL THINKING AND PROBLEM SOLVING SKILLS THROUGH SKILL-ENHANCING GAME

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DEVELOPING CRITICAL THINKING AND PROBLEM SOLVING SKILLS THROUGH SKILL-ENHANCING GAME

ABSTRACT

Reasoning is believed as one of the core characteristics of chess game. Player of the game tend to break down big problems to smaller pieces and then put them back together. Although various schemes and programs have been put into action in the U.S., Canada and some European countries, playing chess is merely regarded as hobby when it should be exploited for increasing child's ability to think critically. This research is an experimental research in observing students' development in critical thinking skills through chess playing. Participants were divided into two groups of student age 10 years old. The first group comprised of students with the ability to play the game and the second group consisted of students who have no prior knowledge of the rules or the strategies of such games. Both groups were subjected to pre-test and post-test involving solving problems in Mathematics, Science, and Critical Thinking test. After 10 weeks of chess intervention, data were analyzed using t-test to compare the mean differences between two groups, and Pearson's test to see correlation between two variables; critical thinking and science, critical thinking and mathematics. Results have shown that chess has the potential as a good tool to develop students' critical thinking skills, although different set of students demonstrate different result. Larger sample size and longer duration of experiment could demonstrate a better result in participants' scores and this can take into consideration for future research.

Keywords: school children, game, science, mathematics

MEMBANGUNKAN KEMAHIRAN BERFIKIR SECARA KRITIS DAN MENYELESAIKAN MASALAH MELALUI PERMAINAN YANG MENINGKATKAN KEMAHIRAN

ABSTRAK

Penaakulan adalah antara elemen utama permainan catur. Pemain catur berkebolehan untuk menyelesaikan masalah besar dengan menguraikan masalah tersebut kepada yang lebih kecil dan kemudiannya disatukan semula membentuk satu penyelesaian. Walaupun pelbagai inisiatif telah dijalankan di serata negara Eropah, Kanada, dan Amerika Syarikat dalam mengekspolitasi permainan catur sebagai permainan untuk meningkatkan kemahiran berfikir para pelajar, permainan catur masih dianggap sebagai permainan untuk mengisi masa lapang sahaja. Tesis ini merupakan satu kajian eksperimentasi untuk menyelidik perkembangan kemahiran berfikir secara kritis oleh pelajar-pelajar sekolah melalui permainan catur. Peserta kajian terdiri daripada para pelajar berumur 10 tahun yang dibahagikan kepada dua kumpulan. Kumpulan pertama terdiri daripada mereka yang mempunyai kemahiran bermain permainan catur manakala kumpulan kedua terdiri daripada mereka yang pernah bermain catur dan tidak tahu tentang peraturan dan strategi permainan tersebut. Kedua-dua kumpulan peserta ini diuji pada awal kajian dan juga di akhir kajian dalam menyelesaikan masalah matematik, sains dan pemikiran kritis. Selepas 10 minggu eksperimen, data dianalisa menggunakan ujian-t untuk membandingkan min antara dua kumpulan berkenaan dan ujian Pearson's untuk melihat korelasi antara dua variabel yang terlibat; sains dan pemikiran kritis, matematik dan pemikiran kritis. Secara keseluruhannya keputusan menunjukkan permainan catur berpotensi sebagai alat untuk meningkatkan kemahiran berfikir secara kritis pelajar walaupun terdapat pelajar yang menunjukkan keputusan yang sebaliknya.

Kata kunci: murid sekolah, permainan, sains, matematik

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CHAPTER 1: INTRODUCTION

1.1. Background of study

As cited in Andrew and Higson (2008), industrial players demand crucial employability skills from their employees particularly college graduates. It is important to note that they highlight the importance of problem solving skills as the essential criteria in order for employees to be effective at workplace. In this case, problem solving skills are perceived by employers as one's ability to think in critical and analytical manners:

> "The discipline (subject content) is not so important, it is the other skills learned at the university that are important. The analytical skills and problem solving skills…" (Andrews, 2008, p.2).

The lack of critical and analytical thinking skills is undeniably one of the main factors on the ramp up of the unemployed college graduates across the globe. This situation occurs due to a more rapid, challenging, and highly competitive business environment in comparison to ten or twenty years ago. As a result, college graduates who are lacking in those skills face difficulties to be employed (Andrews, 2008).

Many similar previous studies conducted among employers have repeatedly shown that the priority of job opportunity is commonly given to graduates who are not only outstanding in their academic achievement but also those with personal transferrable skills that include problem solving. These skills are developed through education system, work, hobby, social, and other life experiences which could be recognized, developed, and applied across a number of settings and contexts. They are unique from one individual to another and have valuable contributions in terms of

career planning and getting a job. In Malaysia, more employers are searching for balanced and holistic potential employers with good academic achievement and possess an assortment of soft skills such as communication, problem solving, and interpersonal (Kaur, 2008).

Science and mathematics are two subjects that comprise the element of critical thinking. Both fields are also part of important elements of the 5 year Malaysian Economic Plan that emphasized the role of science and technology education as a vehicle for economic growth, wealth creation and innovation (Buang, 2009). They are also indicators for self-efficacy and academic achievement of a student (Kesan & Kaya, 2018), which mean students who are excellent in the subjects will also perform in another subjects too.

Bassham (2002) argues that college students are becoming more receptive to new information yet less resourceful especially with the accelerating growth of information technology. They are merely rote learners rather than critical thinkers who often accept raw information as the final answers to a question without analyzing, criticizing, and arguing coherently. This has led to a bias and egocentric type of judgment (Bassham, 2002). In this case, the integration of critical thinking skills in the academic curriculum should be implemented among students as early as their elementary years. Besides training these children to solve real issues or problems more effectively, this early exposure also helps them to prepare for their higher education in future.

1.2. Statement of problem

The field of science and technology with its application has been the foundation for economic and industrial development of the world. Every year, there is a high proportion of graduates in the fields of science, mathematics, engineering, and many other courses that correlate with the use of technical skills for those who join the workforce. In Malaysia, the percentage of graduates who have successfully completed the final year of their tertiary studies in science and engineering has displayed a declining trend since 2006. The Human Development Index (HDI) shows that the figures have reduced from 42.3% in 2006 to 37.7% in 2011 (UNDP, 2011). Table 1.1 shows the percentage of graduates taking science and engineering courses and completed their studies in Malaysia since the year 2006 until the year 2011.

Table 1.1: Percentage (%) of students taking science and engineering

Year	Graduates in Science and Engineering (%)
2006	42.3
2007	45.4
2008	40.2
2009	37.7
2010	Not available
2011	37.7

Source: Human Development Report (UNDP, 2011).

Many researchers agree that skills and interests in science and mathematics should be nurtured and developed since the early years of a child's education. School children should be well-equipped with those skills in preparing them for a more challenging environment in the secondary and tertiary level of education. As far as the literature is concerned, problem solving skills have been broadly explored and discussed from various perspectives for example in practical problem solving, practical

intelligence, everyday problem solving, personal problem solving, and social problem solving (D'Zurilla et al., 1998). Goldin (1998) and Nunokawa (2005) further argue that problem solving skills are mainly associated with the skills acquired while learning mathematics and science.

Although there are other studies on problem solving skills that have been conducted on other subjects, the skills in learning mathematics and science at schools are the skills that mainly contribute to students' ability to think independently (Coleman, 1998; Wickman, 2002; and Chang & Taipei, 2010). Therefore, an international assessment to test out students' skills in reading, mathematics, and science called Program for International Student Assessment (PISA) has been organized by The Organization for Economic Co-operation and Development (OECD) since the year 2000. It is an assessment that examines students' readiness for adulthood and the acquisition of important skills in their lives. Thus, questions imposed in PISA test is based on real life scenarios with three domains being tested among students which are mathematics, science, and reading (OECD, 2014a).

Malaysia has been participating in PISA test since the year 2009 which so far the country demonstrates a declining trend in students' overall performances in all three domains. This has placed Malaysia amongst 20 countries with the lowest scores such as Montenegro, Kazakhstan, Jordan, and Indonesia. In PISA 2009, Malaysia ranked 57th out of 74 countries participated while in PISA 2012 the rank went down to 61st out of 64 countries (OECD, 2014b; Tehrani, 2014). In comparing scores between domains to that of the mean scores for OECD which is 500, for mathematics, Malaysia has scored 404 in 2009, 421 in 2012, and 446 in 2015; for science, Malaysia has scored 414 in 2009, 420 in 2012, and 443 in 2015; for reading, Malaysia has scored 422 in 2009, 398 in

2012, and 431 in 2015 (OECD, 2014b). Table 1.2 shows the performances between domains.

Table 1.2: Malaysian students' scores in PISA

Year	Mathematics	Science	Reading
2009	404	414	422
2012	421	420	398
2015	446	443	431

Source: PISA Results (http://www.oecd.org/pisa/)

According to the scores in Table 1.2, it could be seen that Malaysia is currently performing below the international average scores in the areas of mathematics, science, and reading. The average score is 500. It is also stated in the statistics of OECD (2014d) that about 45% to 60% of the Malaysian students score below the average scores in all subjects, and almost none of them demonstrate higher order thinking skills especially in problem solving in any subject. The statistical figure produced by the Ministry of Education in 2013 has shown that no Malaysian students score the level 6 of thinking skills' assessments and only 0.1% students manage to score the level 5 of thinking skills. In contrast with Malaysia's neighboring country, Singapore managed to score at level 6 in PISA 2012 assessment particularly in problem solving.

From the statistics, 56% students in that country are able to solve complex problems and less than a third of all students in OECD countries are able to do the same (OECD, 2014c). On the other hand, another international assessment similar to PISA is Trends in International Mathematics and Science Study (TIMSS). This assessment is slightly different with PISA in the sense that it examines the curriculum content of Mathematics and Science subjects learned by students at schools. Organized by the International Association for the Evaluation of Educational Achievement (IEA), the test

is conducted once every four years starting in 1995. It consists of two domains which are mathematics and science (International Association for the Evaluation of Educational Achievement, 2013a). Malaysia has been one of its participants since 1999.

In this test, Malaysia's scores have also been performing under the international average which is 500. Scores for mathematics went down from 519 in 1999 to 440 in 2011, showing a significant decrease of 79 points. At the same time, the scores for science went down to 426 in 2011 from a higher score of 492 in 1999 (IEA, 2013b). Table 1.3 shows the comparison between domains while Table 1.4 shows Malaysian students' ranking in the study from the year 1999 until the year 2015.

Table 1.3: Malaysian students' scores in TIMSS

Year	Mathematics	Science
1999	519	492
2003	508	501
2007	474	471
2011	440	426
2015	465	471

Source: TIMSS Results (http://timss2015.org/)

The 2011 TIMSS results show about 35% of Malaysian students score below international average score that is 500, in Mathematics subject and 38% Malaysian students score below the international average score in Science subject (Ministry of Education, 2012). In this case, results in PISA and TIMSS are one of the main references for Malaysia's Ministry of Education to plan its national education transformation. This is the basis for Malaysia Education Development Plan 2013-2025, the latest national blueprint for educational development plan from pre-school level up to post-secondary education (Ministry of Education, 2012).

Table 1.4: Malaysia's ranking in TIMSS from the year 1999 until 2011.

Year	Mathematics	Science
1999	16	22
2003	10	20
2007	20	21
2011	26	32

Source: TIMSS Results (http://timss2015.org/)

Other than that, Forneris et al. (2007) discovers that teaching and learning programs that apply interactive approach have stronger effects than learning programs that are purely based on informative learning in order to develop students' ability in solving problems more effectively. This is also perceived as a non-interactive, traditional, or rote learning method.

For example, he has conducted an interventional study on 20 Canadian adolescents in 2001 with the main objective to teach participants a problem-solving strategy. The strategy known as STAR consists of few steps to be taken by a problem solver in order to solve a problem; firstly take a deep breath, then think of other alternatives to the problem, next anticipate the consequences for each alternative, and finally respond to the problem with the best choice of solution.

The best solution is the one that gets the problem solver closest to his or her goal (Forneris et al., 2007). This study has shown that the participants are becoming more aware of the steps that need to be taken whenever they have problems to solve in their academic or daily lives as opposed to that of control group. They have also been taught that each step is necessary and should be specific, including by having clear visions to reach their missions or goals. Previous researchers have also argued on various methods to develop students' critical thinking and problem solving skills including role play,

games, and collaborative learning (Mohamed & Maker, 2011; Raphael et al., 2012; and Adams, 2012). For instance, playing numerical board game is believed to be effective in improving students' knowledge on numerical magnitudes (Siegler & Yan, 2008).

Table 1.5: The attributes of traditional and experienced-based teaching and learning activities

Traditional Paradigm	Experienced-based Learning
Teaching and learning = stimulus and response	Learning is mediated by socioemotional and physical environments
Passive, memory-based learning	Active, collaborative, critical thinking, analysis, problem solving, and evaluation
Learner watches and listens to teacher	Learner interacts and collaborates with adults and peers
Learners learn what teachers teach, standardization leads to mediocrity	Diverse learners and learning environment lead to creativity
Knowledge is most often assessed by written examination	Knowledge is assessed as the way it is being applied through projects, presentations, and multimedia
Predictable, static, and unchallenging = boring	Fun, challenging, relevant, multimedia presentation = engaging
Books, articles, lectures, and examinations	Simulations, games, role-plays, case studies, encounter groups, and multimedia

Source: Hromek & Roffey (2009)

Besides that, interactive classroom activity or also known as the experience-based learning tool is like a game that provides a platform to develop students' social and emotional learning skills such as being responsible to oneself and others in making ethical decisions, being able to set goals for short and long term, as well as problem solving skills especially in personal coping domain and interpersonal relationship domain (Hromek & Roffey, 2009). It requires both teachers and students to be active participants in the classroom**.** Table 1.5 shows the differences between the features of traditional paradigm and experience-based teaching and learning activities.

Hromek and Roffey (2009) argue that games are administered by rules which need to be abided and followed by players. In order to get the attention of children, games are played by keeping a balance between chances, skills, strategies, hopes, and a moderate control of the intensity of competitiveness. Players focus on their goals to win the games while at the same time coping with other elements in the games such as time checking and analyzing the opponent's moves to plan few steps ahead of their opponents. These actions are traditionally found mostly in the game of chess. Ferreira and Palhares (2008) further argue that games which integrate the elements of strategic thinking skills especially chess contribute to the development of mathematics and problem solving skills of third to sixth grade students (Adam, 2012).

The ability to recognize patterns and common strategies involving problem solving is perceived to be on the most important skills possessed by chess players which could later be transferred to other areas of learning or disciplines of knowledge such as science and mathematics. However, although many schemes and programs have been introduced and realized into actions in the United States of America, Canada, and few other European countries, playing chess, according to Tudela (2009), Vail (1995), and Atherton (2007), is still merely regarded as a hobby or simply a tournament game when it should have been applied in positive way particularly for the purpose of enhancing children's ability to think critically.

In the context of Malaysia's education system, this effort is congruent with the aspiration of the Ministry of Education that hopes to see more efforts are taken in improving, planning, and implementing a suitable approach and pedagogical content for teaching and learning activities at schools. Besides providing more advanced facilities and infrastructures at schools as well as recruiting more teachers and staff, Malaysia's

incumbent Prime Minister, Dato' Seri Mohd Najib Tun Abdul Razak, specifically aims to transform the national education into what is called as a world-class 21st century education to the younger generation of Malaysians (Abdul Razak, 2013).

1.3. Research questions

This study is carried out to determine the effectiveness of chess in developing critical thinking and problem solving skills of participants. Participants have been divided into two groups (chess group and control group). The chess group has been exposed to ten weeks of chess lessons, conducted by researcher and facilitators, while control group follow conventional school lessons without following any chess lesson or such program. Pre and post-test has been ministered to both groups. There are several dependant variables involved in order to answer the research questions.

The California Critical Thinking Skills Test (CCTST) is among the tests administered to participants that will show improvements on critical thinking skills in participants. Based on previous literature, it can be anticipated that if there is a difference in participants' performance in all the tests administered, students who were involved in chess and who were not will have different level of cognitive development. Result will show the difference in participants' achievements before and after chess lessons is implemented. Given that there is sparse literature on the direct impact of chess playing to students' academic performance (Sala & Gobet, 2016), this study proposed a non-directional hypotheses for each research question:

Question i: Does playing chess improve critical thinking test scores of the experiment group?

Hypothesis: There is a significant difference in the pre-test scores and post-test scores of the California Critical Thinking Skills Test (CCTS) within

experiment group. That means students who were involved and who were not involved in chess playing will show different results in their critical thinking test.

Besides critical thinking skills, chess lesson is argued to improve mathematics skills of participants. Therefore, school's mathematics test is administered to participants before and after chess lessons is conducted. It will show the difference in participants' results. Thus, the test will answer this question:

Question ii: Does playing chess increase mathematics test scores of experiment group?

Hypothesis: There is a significant difference in the pre-test scores and post-test scores of the mathematics scores within experiment group. That means Students who were involved and who were not involved in chess playing will show different results in their mathematics scores.

The other school's subject concerned with this research is Science. It is argued that students with good critical thinking and problem solving skills will also projects good scientific skills, as Science subject concerns with one's ability to apply knowledge and related skills to solve problems. In this case, we ought to answer the next research question:

Question iii: Does playing chess increase science test scores of the experiment group?

Hypothesis: There is a significant difference in the pre-test scores and post-test scores of the science scores within experiment group. That means Students who were involved and who were not involved in chess playing will show different results in their science scores.

In this research, it is also significant to observe the relationship between critical thinking skills and other subjects learned in school. In this case, science and mathematics subjects. Therefore, Pearson's correlation test will be conducted to answer these questions:

Question iv: Is there any correlation between critical thinking skills' test performance and students' scores in mathematics test?

Hypothesis: Pearson correlation test shows significant correlation between students' CCTST scores and their end-of-the-year scores in mathematics test.

Question v: Is there any correlation between critical thinking skills' test performance and students' scores in science test?

Hypothesis: Pearson correlation test shows significant correlation between students' CCTST scores and their end-of-the-year scores in science test.

There were two schools participated in this study for the purpose of obtaining a significantly reliable result through the appropriate sample size. The result would then be presented according to each hypothesis being tested to every school, starting with school A and followed by school B.

1.4. Research objectives

This study is concerning with (i) the effects of chess playing on participants' critical thinking skill, (ii) the effects of chess playing on participants' score in mathematics, (iii) the effects of chess playing on participants' score in science. Science and mathematics are two critical subjects in school that requires students' problem solving skill in order to understand the context learned. Participants are students from

elementary schools aged 10 years old (grade 4), subjected to pre and post-test of critical thinking, mathematics and science assessments.

Previous studies on chess and critical thinking has showed that chess enhances players' verbal and non-verbal reasoning, memory span, analytical skill, inductive and deductive reasoning (Dauvergne, 2000; Garcia, 2008). Those elements in chess are testable using the California Critical Thinking Skills Test which comprises 20 questions revolving daily life. It consists of seven elements that test students' critical thinking skills; analysis, interpretation, inference, evaluation, explanation, deductive and inductive reasoning (Facione & Gittens, 2012).

As mentioned earlier in this section, due to sparse literature on observing direct impact of chess to students' academic performance, this study satisfy with the non-directional hypothesis to answer each research question. This means that students who were involved (experiment group) and who were not involved (control group) will demonstrate different results in all the tests administered, at the end of the study. Besides that, there are two sub-objectives for this study:

i) To correlate critical thinking skills with science subjects using Pearson's correlation test;
ii) To assess correlate critical thinking skills with mathematics subjects using Pearson's correlation test.

1.5. Theoretical framework

The ongoing research and development of science and technology as well as the current technological advancement in various fields of knowledge have stimulated and encouraged a massive amount of innovations to take place in the market particularly in the creation and development of new and existing products. It has also transformed the way knowledge and information being shared and delivered between the experts and the laymen.

Due to this rapid change in our societies today, many efforts have been put forward by teachers and schools to introduce few suitable approaches in teaching and learning activities through the improvement of current academic syllabus or through the development of new curriculum programs. For example, since 2014, the Malaysia's Ministry of Education has been working on improving the content of the current syllabus of all subjects including Mathematics and Science at school with local television programs by embedding the elements of critical thinking skills in these subjects' teaching and learning activities.

Next, developing students' higher order thinking skills through the application of games has been proven in many studies [(Caldwell, 1998); (Ascher, 2001); (Howes, 2002); and (Woodman, 2006)]. On the other hand, Barrios et al. (2017) believes that games provide interactive learning through a variety of problem solving activities and Anderson (2004) states that students are able to focus their attention on given tasks or responsibilities longer than any other conventional learning would.

Strategies of games, according to Ascher (2011), provide clearer and well-defined goals, as well as a comprehensive set of permissible actions to reach that

particular goals. Players are exposed to many options and alternative ways in attaining the goals but each step requires a careful and thorough thinking procedure due to its two-sided logical implications. This study is based on the premise that learning intervention via instructional games such as chess enhances students' critical thinking and problem solving skills (Litrap, 1992; Rifner, 1992; Ferguson, 1995). It is argued that games facilitate the development of spatial skills, two-dimensional mental rotation, general problem solving strategies, mathematical reasoning skills, as well as metacognition and planning skills (Blumberg et al., 2013).

Every game enhances different aspects of mental cognition due to their differences in nature (Oei & Patterson, 2013). Among the most cited studies on chess and students' academic performances are Rifner (1992), Ferguson (1995), and Liptrap (1997). Ferguson has consistently conducted many researches on chess and its impacts on students' thinking skills. His study started as a doctoral dissertation entitled 'Developing Critical and Creative Thinking through Chess' before his exploration on the differences of various learning methods that could stimulate the development of critical and creative thinking skills among students (Ferguson, 1995).

A research project that was funded by the federal government to selected students in their 7^{th} to 9^{th} grades in the Bradford Area School District, Ferguson (1995) divided them into three groups which were chess treatment, computer treatment, and a combination of all non-chess treatments. Each group met once a week over the period of 30 weeks, spending a total of 60 to 64 hours of intervention. Pre-test and post-test were administered to students using the Watson-Glaser Critical Thinking Appraisal (WGCTA). Results indicated that chess group's average scores experienced an increase that outperformed national average scores. Specifically, the analysis on the critical

thinking appraisal showed that chess group demonstrated a significant difference than the other groups in the study (Ferguson, 1995).

Ferguson's two earlier studies also showed a positive increment in the performance of chess group. The Tri-State Area School Pilot Study in 1986 showed that the chess group produced the most significant increment in the test scores as compared to the Scholastic Assessment Test (SAT) preparation group; SAT group $p>0.24$ and chess group $p>0.004$. In a study entitled Development of Reasoning and Memory through Chess from 1987 to 1988, Ferguson used a more intensify approach by administering chess lesson on a daily basis to the participants. Findings discovered that participants did show a significant increase in the Memory subtest in the Test of Cognitive Skills (TCS) Memory subtest and the Verbal Reasoning subtest from the California Achievement Tests battery.

The differences in results of the pre-test and post-test were then measured statistically using the *t*-test of significance. Gains on the tests were compared to national norms as well as within the experiment group. The differences between males and females on the tests were also examined.

In another study, Rifner (1992) conducted a research on the transfer of problem solving skills from one domain to another which in this case from chess playing to transfer task of poetic analysis. It was a doctoral dissertation with the title 'Playing Chess: A Study of the Transfer of Problem Solving Skills in Students with Average and Above Average Intelligence'.

Rifner's study was conducted on the basis of Perkins and Solomon (1988, 1989) argument that states there is evidence of the occurrence of skills and knowledge being transferred while players play the game of chess. Thus, the main goal of the study was to determine whether learning to play chess enhances problem solving abilities in a manner which permits the application of a remote transfer task. The training task then involved learning to play chess, and the transfer task required poetic analysis (Rifner, 1992). However, Perkins and Solomon in 1988 and 1989 contend that transfer could occur between two different domains and that it could be obtained when students are taught general reasoning principles; where, when, how to apply them, and how to monitor the results of their application of those principles (Rifner, 1992).

Findings of the study also showed that experiment was effective in developing skills in chess and that transfer could be achieved if teaching for transfer is the instructional goal. Moreover, a study conducted by Liptrap (1997) about chess and standard test scores documented the effects of participation in the chess club upon the test scores of elementary school students. For this purpose, four elementary schools in a large suburban school district near Houston, Texas were selected. All schools established chess club and maintained it for at least two years. No chess instruction was carried out during school hours. By using all students who participated in the school's chess club as respondents, Liptrap (1997) had a large sample of 571 students from all four schools. This element was the extension of Ferguson's study that used small sample of participants.

The study found that regular students showed significant difference in Texas Learning Index. It was discovered that chess players showed significant improvement as opposed to non-chess players. There was also no significant difference in reading scores

of third grade students while fifth grade students showed a significantly high difference in the scores. In the mathematics scores, there was significant difference between both groups. The chess group outperformed the non-chess group. Other than the findings, Liptrap (1997) argues that chess should never be a substitute for instructional strategies and teaching methodologies in any subject at school but as an enrichment or supplement activity.

This is mainly for students with average ability. As far as the research on chess and academic achievement is concerned, Barrett (2010) and Berkley (2012) studies on chess and critical thinking skills found significant correlation between these two domains. The chess groups in both studies showed significant improvement in their achievements in mathematics. Barrett (2010) administered chess instruction on students who received special education services in mathematics classes. Participants were in their sixth, seventh, and eighth grades. Researcher examined the effects of chess instruction for 30 weeks using pre-test and post-test analysis design. Both experiment and control groups were assessed using Texas Assessment of Knowledge and Skills (TAKS) and their achievements in mathematics via end-of-the-year course.

It was also found that students who received chess lessons outperformed students who did not attended chess lessons in the mathematics achievement measures, although they received less hours of regular lessons in mathematics. In terms of transfer skill, research findings support the conclusion that transfer occurs within the experiment group (Barrett, 2010).

Another study conducted by Berkley (2012) showed an improvement in mathematics achievement by the experiment group although they did not improve in

critical thinking ability test. The test was Watson-Glaser Critical Thinking Appraisal (WGCTA). This discovery was consistent with the finding that demonstrated weak correlation between pre-test critical thinking scores and pre-test mathematics scores (Berkley, 2012).

Berkley's study was guided by the theory of transferring cognitive skills as suggested by David Perkins and Gavriel Solomon in 1988 in their article entitled 'Teaching for Transfer'. They believe that transfer of cognitive skills is possible and the process of transferring depends on the nature under two conditions where the process occurs which are near transfer and far transfer (Berkley, 2012). Near transfer is a condition where the source and target of transfer are very similar, for example, mathematical concepts learned in the classroom could be transferred to a task in answering mathematics examination questions. Hugging technique is used during the transfer process (Salomon & Perkins, 1989). The transfer process would occur naturally and almost automatically if students put in a great deal of practice.

On another note, far transfer is a transfer process that occurs between two different domains or different context. For example, a general problem solving skills practiced while playing chess are applied in daily problem solving activities. This requires the technique of bridging. Students must be able to find some connections between two different domains and apply the theory. In this case, researchers find far transfer as being more difficult to achieve than near transfer. Solomon (1989) states that it requires cognitive understanding which includes conscious analysis, mindfulness, and application of strategies that cut across disciplines.

Through mixed-method study, Berkley explored participants' views on the intervention to provide clearer perspectives with regards to his study. Six participants were interviewed, and positive relationship between chess and critical thinking was discovered. The participants admitted that they learned to solve problems through the game of chess. This was, according to Berkley (2012), due to nature of the game that provides a great amount of problems to be solved. Studies by Rifner (1992), Ferguson (1995), Liptrap (1997), Barrett (2010), and Berkley (2012) ascertained that chess has a positive impact on the performance of students in terms of their academic performance, problem solving, critical thinking, creative thinking, and mathematical skills.

On the other hand, it is also important to note that different test instruments would produce different findings, depending on the goals of each study. In addition, Massey (2005) and Barclay et al. (2011) explored the use of educational games in courses available at higher learning institutions particularly information system and pharmaceutical practices. Both studies demonstrated favorable findings whereby each of them contributes to the development of students' academic performances. As for elementary school children, in regards to mathematics skills, board games help children understand the magnitudes of numbers, to estimate, to count, and to identify the right numbers precisely (College, 2013).

Caldwell (1988) for instance argues that games such as Monopoly and Scrabble provide tremendous learning experience to children. In Monopoly, children are able to learn about the concept of probability from the elements applied in the game. The projects in the game illustrate real-life events in managing and trading properties, thus discussions in the game revolves around selling and buying assets to sustain good properties (Caldwell, 1988). Yoon (2014) also believes that games facilitate active

learning and increase knowledge retention. He adopts important ideas from Monopoly and creates an educational healthcare game called Foley-opoly. The game is designed following the journey of a patient from the admission to the hospital until the process of discharging from the hospital.

Each participant uses different colors of pieces for identification purpose. Incentive is rewarded to good healthcare practices with advanced spaces given while the bad healthcare practices would lose a turn or have to move backwards (Yoon, 2014). On the basis of the studies being discussed, this study therefore seeks to explore the effectiveness of chess intervention on participants' critical thinking and problem solving skills.

Following this, framework of this study starts with the main problem encountered where Malaysian students seem to perform poorly in two international cognitive skills' indicators which are the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS).

This situation calls for new approaches that could be effective in developing students' critical thinking and problem solving skills. Participants are therefore exposed to a period of chess training program after which they are subjected to the California Critical Thinking Skill Test (CCTST) and school's examinations for Science and Mathematics subjects. Figure 1.1 shows the relations between critical thinking, chess, science and mathematics in this study.

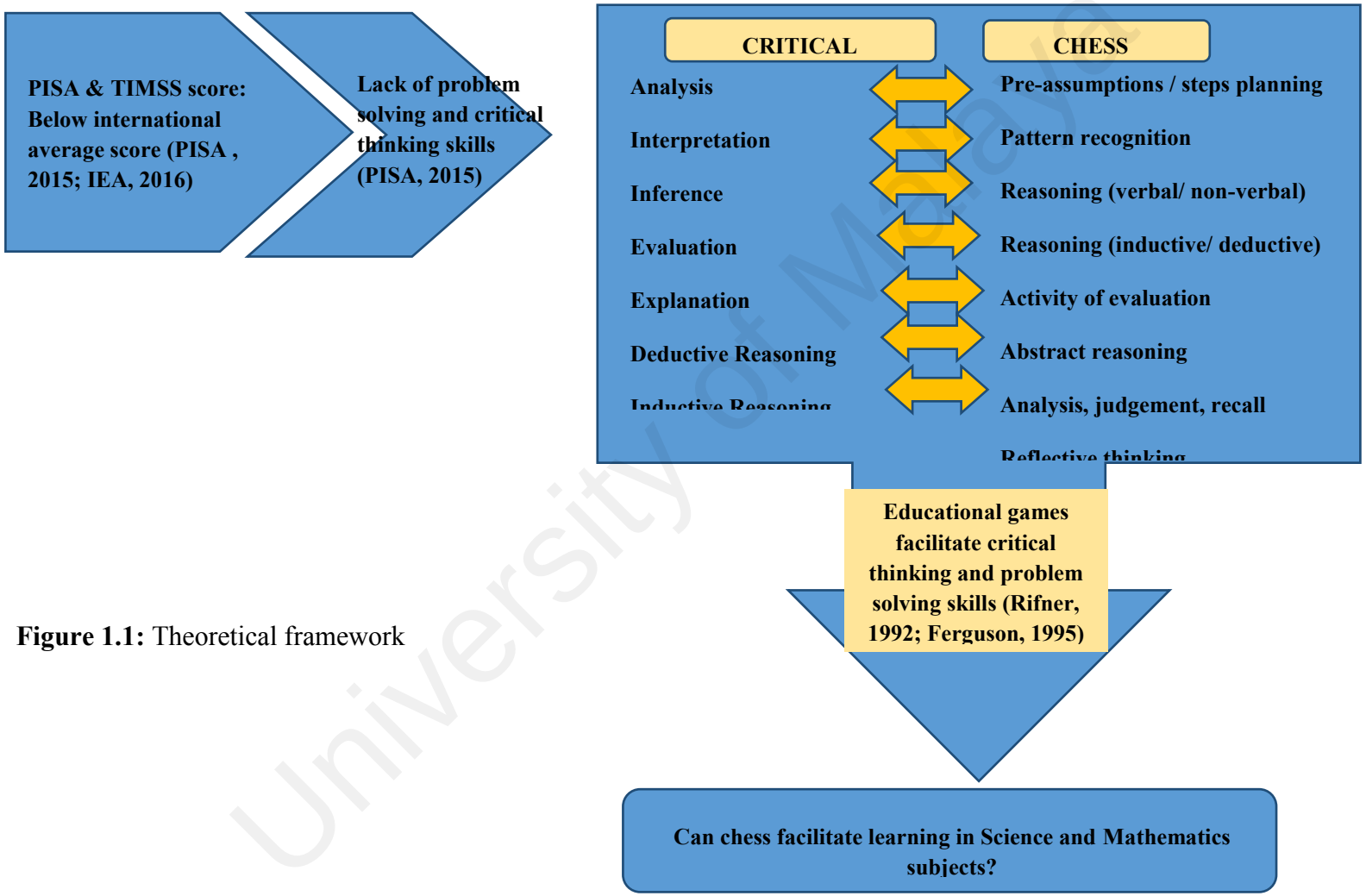

Figure 1.1: Theoretical framework

1.6. Significance of study

There have been many attempts by educators and scholars to find appropriate approach to develop students' critical thinking and problem solving skills. Such attempts could be seen in previous researches and initiatives in Canada, United States of America, and few other European countries (Rifner, 1992; Ferguson, 1995). In spite of that, chess is still merely regarded as a game which is played as a hobby or during tournament when it should have been perceived as an educational instrument to develop students' thinking skills particularly in Malaysia. On top of that, critical thinking skill is taught in a traditional classroom setting using traditional teacher-student approach which only allows one-way communication rather than a dynamic interaction among members in the class such as during chess instruction (Zabit, 2010).

Therefore, findings of this study would also lead to another relevant data to the planning of teaching methodologies or instructional strategies that could be applied by teachers with the integration of critical thinking skills in the classroom particularly in Malaysia. This study aims to benefit each individual in the experiment group in the sense that it exposes many advantages of playing chess especially in developing their thinking skills. Such opportunity is significant as they normally have to pay quite expensive fee for a professional chess coach. Only well-off children could have the opportunity. Besides, this study is systematically designed to develop both chess skills and critical thinking skills through the contents and contexts being presented during instructions using two-pronged approach.

As mentioned in the beginning of discussion, chess could be used as a pedagogical tool to promote active learning in the classroom. Dorestani (2005)

suggested that active learning occurs when students are encouraged to engage in interesting activities other than listening to what the teachers are teaching in the classroom. This method is different to that the one found in a traditional classroom setting whereby learning only allows one-way interaction. In a traditional learning setting, teachers would master the instructional materials and pass the knowledge to students. Students would then simply receive the information given without further discussions. In contrast with this study, this learning method or approach is regarded as passive learning or teacher-centered paradigm.

The approach conducted in this study which is active learning has proven to be effective in many educational researches related to economics, business studies, and engineering (Graham, 1992; Dorestani, 2005; Fowler, 2006). Next, the reason why researcher uses chess over other board games is because of its distinctive feature which is notation writing. While playing chess, students need to record all the moves they have made and the positions of pieces on the chess board so they could revise that particular moves whenever they want. The standard notation that is currently and widely used is the algebraic chess notation. It consists of 64 squares; eight rows and eight columns, with 32 pieces arranged in two alternating light and dark colors.

It supports continuous attempts in improving teachers' instructional strategies, teaching methodologies, and assessment of critical thinking skills in education. Data collected in this study would provide significant premises in developing researches on alternative strategies to develop critical thinking skills among students besides the concurrent traditional approach. This is due to previous studies that support the notion that playing and studying chess have positive correlation with individuals' cognitive abilities.

Those researches aim to accommodate various learning conditions including students with learning disabilities. In addition to that, transfer is acknowledged as a theory commonly found in those studies. If it is the case that chess does improve critical thinking skills, therefore chess could play a bigger role not only in education but in all aspects of our lives.

1.7. Delimitations of study

This study uses only elementary school children as its research subject thus making this study not generalizable among students in higher level of education such as in secondary, tertiary, or post-tertiary levels. The selection is based on the premise that critical thinking instructions should be introduced to the education system at the very early stage of students' lives. The promotion of playing chess as an effective method to encourage active learning in the classroom would also expose students to many other advantages of the game besides merely taking it as a hobby. Second delimitation is the amount of time to complete the chess instruction as well as the sources used for these instructions.

The chess curriculum is designed according to the Malaysian Chess Federation standard. It is discovered that the standard is recognized worldwide and applicable to this study. Most importantly, it is tailored to suit critical thinking instructions at school for teachers to follow. The amount of time used to teach this curriculum may not necessarily be enough to greatly improve students' critical thinking skills because of the challenges in scheduling the students. The only availability is during school time, therefore researcher needs to fit the game into their schedules.

However, it is also one of researcher's objectives to focus on the quality of chess instructions delivered as opposed to the amount of time spent and therefore, the third delimitation is the number of participants in the study and its non-randomness. In this research, there are 41 students in school A and 35 students in school B who are divided into two groups, the control group and the experimental group. A small number of students allows researcher to give focus on each student during chess instruction to ensure that they understand what have been taught by the instructor. The randomness of sample occurs within each different level of grades selected by researcher. All participants are fourth grade students.

The selection of one grade would allow researcher to exercise control over other factors such as there are different teachers involve during students' normal classroom learning or different level of education in their curricular system. With that, researcher assumes that participants have almost similar level of academic development and achievement. Lastly, this study is limited to two elementary schools located in a suburban public school district within the Klang Valley, Malaysia. Thus, the results of this study should not be generalized or the analysis might not be applicable to other locations in Malaysia due to other elements that may affect the data collected such as demographic, socio-economics, and technological factors, among others.

1.8. Limitations and assumptions of study

In carrying out a longitudinal study, a researcher has to conform to its external factors that would affect the duration of the fieldwork. Such examples in this study are the syllabus and co-curricular activities that need to be completed by schools by the end of the year in fulfilling the requirement imposed by the Malaysia's Ministry of Education. Thus, this study is limited to ten weeks of chess intervention. The study

begins with the execution of pre-test and post-test of the CCTST as well as the science and mathematics tests. It is expected that all participants would complete the pre-test and post-test of the CCTST. No students are expected to stop attending the chess instruction for the experimental group and no students would withdraw from this study since the intervention is completed during normal school time. Other than that, there is no random assignment given to students.

As mentioned earlier, participants are fourth grade students. Fifth and sixth grade students are not advisable to be interrupted as they are focusing on their preparation for *Ujian Penilaian Sekolah Rendah (UPSR)*. UPSR is a standard assessment designed for Malaysia's elementary schools that students take at the end of their elementary school years. Besides that, this study is limited to two public elementary schools due to the limited amount of time available to conduct chess intervention since students' schedules are subjected to schools' availability. Besides, it is difficult to get approval from those schools since intervention uses normal school time. Lastly, since this study is limited to fourth grade students only, the sample size is relatively small consisting of 41 students in School A and 35 students in School B, both in the control and experimental groups. Study is also limited to the Klang Valley area.

CHAPTER 2: LITERATURE REVIEW

2.1 What is critical thinking?

The concept of critical thinking emerged as early as 2,500 years ago when Socrates discovered that people could not justify their claims rationally, but rather blindly accept other people's claim based on the authority that the a person has (Paul, Elder, and Bartell, 1997). Socrates argued that a person might have power and authority yet still feeling confused and irrational. Probing the right question would help a person deals with this issue as recommended by Socrates. In response to this premise of argument, the concept of critical thinking has been widely employed in many disciplines of study therefore there is neither a generally accepted definition of critical thinking nor a single definition of this particular subject (Broom, 2011). On the other hand, referring critical thinking as reflective thinking, John Dewey (1918; 1933) as cited in Bessick (2008) defines critical thinking as;

> "An active, persistent, and careful consideration of a belief or supposed form of knowledge in light of the grounds which support it and the further conclusions to which it tends." (Bessick, 2008, p.26).

The word or phrase active here refers to a dynamic mind seeking solution to problems, probing with the right questions, and also by engaging in a mind challenging conversation between two or more individuals. This value could be instilled and nurtured within the human mind through mind-engaging activities like strategy games. The term persistent, on the other hand, is related to John Dewey's perception of habits or dispositions. Nurturing this habit is time-consuming to which he argues;

> "The basic characteristic of habit such as socially shaped disposition is that every day experiences enacted and undergone modifies the one who acts and undergoes, while this modification affects, whether we wish it or not, the

> quality of subsequent experience… The principle of continuity of experience means that every experience both takes up something from those which have gone before and modifies in some ways the quality of those which come after." (Lyutykh, 2009, p. 378)

Both persistent and active are the important elements of critical thinking, and according to John Dewey, could be cultivated through series of experiences a person undergone in his life. This shows that critical thinking not only is a space-bounded activity in which a person is thinking within himself, but also a surrounding-affected activity which a person develops through interactions with his environment. Emphasizing on relevant skills that a person should have, Robert Ennis as cited in Broom (2011) has defined critical thinking as;

> "Reasonable, reflective thinking process that is focused on deciding what to believe and do." (Broom, 2011, p. 18)

The term reflective thinking in the above definition refers to the awareness a person has in search for logical and valid reasons, while the term focused is associated with the activity of thinking that is based on sensible reasons and consciously focuses on goals. Next, the phrase 'deciding what to believe and do' explains that the activity of thinking is closely associated with the evaluation of beliefs and actions by a person (Daniel & Auriac, 2011). The latter also shows that one's actions and judgments are parts of critical thinking process. In this case, the process of critical thinking involves several crucial steps and consists of few complex cognitive skills as identified by Robert Ennis as cited in Broom (2011).

These include one's ability to judge the credibility of sources, to identify conclusions, to provide reasons and hypotheses, to appreciate the quality of an argument, to develop and defend a point of view, to ask relevant questions, to search for

logical reasons, and to draw conclusions that are credible and viable (Daniel & Auriac, 2011). In addition, Broom (2011) also highlights other significant points such as being well informed, able to develop and judge the quality of reasoned arguments, as well as understand how to distinguish between well-reasoned statements and assumptions. Other than that, Robert Ennis formulates the term 'virtues', referring to certain dispositions in critical thinking that a person should possess in order to apply critical thinking skills effectively in every aspect of his life.

The term 'virtues' is a combination of attitudes and inclinations; the obligation about getting things done rightfully, the concern about being honest and clear about what a person thinks, writes, and says, as well as the care about the worth or dignity that every person is entitled to (Ennis, 1996). By combining those abilities and dispositions, he believes that one would be able to improve his thought process efficiently. Virtues are important to demonstrate that even though the concept of critical thinking could be expressed in variety of ways, its essence would always remain the same. Furthermore, critical thinking is a vital process in assessing and analyzing thinking to improve one's cognitive abilities.

It has some basic structures in thinking, which are the elements of thought and basic universal intellectual standards (Elder & Paul, 2010). Richard Paul, a prominent contemporary scholar in critical thinking, is also highlighting the importance of intellectual standards in one's thinking process. He views critical thinking as an activity of 'thinking about thinking' that also implies the concept of 'conscious thinking' as introduced by Robert Ennis as cited in Broom (2011). He defines critical thinking as;

> "A unique kind of purposeful thinking in which the thinker systematically and habitually imposes criteria and intellectual standards upon the thinking,

> taking charge of the construction of thinking, guiding the construction of the thinking according to the standards, and assessing the effectiveness of the thinking according to the purpose, the criteria, and the standards" (p.17).

Paul also opposes educational methodologies that emphasize on rote learning, an approach which is termed the 'anti-intellectual culture' (Broadbear & Keyser, 2000). It is teacher-centered, passive, monotonous, non-dynamic, and uninteresting. He states that students should be able to recall what they have learned in the classroom using their own words and not copying the exact words as in the textbook or teachers' notes. This approach would train the students to understand the concepts or context of learning effectively. It would also promote creative thinking in learning. Furthermore, Paul emphasizes that critical thinking is not an innate skill or natural ability and therefore, it needs to be taught explicitly.

Various approaches could be applied to develop this skill for example though inquiry-based learning, problem solving activities, decision making activities in the classroom, among others. These activities promote students to make connections across subject areas and disciplines (Kenney, 2013). Additionally, in an interview by Think magazine in April 1992, Paul elaborated his definition of critical thinking as an intention of self-improvement through one's own thought process. He said;

> "…critical thinking is thinking about your thinking while you are thinking in order to make your thinking better. Two crucial things are that critical thinking is not just thinking, but thinking which entails self-improvement, and this improvement comes from skill in using standards by which one appropriately assesses thinking. To put it briefly, it is self-improvement (in thinking) through standards (that assess thinking)… To think well is to impose discipline and restraint on our thinking by means of intellectual standards… The dimension of critical thinking least understood is that of intellectual standards…" (Paul, 1995, p. 8)

In his definition, he highlights on the standards that should be imposed in assessing our own thinking or state of mind. This conscious activity of 'thinking about thinking' or reflective thinking is conducted for self-improvement in many activities including decision-making process in our lives, improving academic performance, and solving problems at the workplace. Besides purposeful thought and thinking for self-improvement, Paul and his associate, Linda Elder, also offer a list of elements of thought. These are purpose, information, inferences or conclusions, concepts, assumptions, points of view, and implications or consequences.

First of all, the element of information in thinking process must have nine qualities in order to make messages useful which are clarity, accuracy, precision, relevance, depth, breadth, logic, significance, and fairness (Petress, n.d.).These qualities are also termed as 'universal intellectual standards'. Furthermore, he argues that most teachers are lacking in these standards and are misguided when assessing students' writing or speech performances (Thinking, 2009). For example, they tend to simply grade a fluent, entertaining, and amusing essay as a piece of work that has a high standard of critical thinking.

In addition to that, Fisher (2002) profoundly elaborates what Dewey (1933) means by the term critical thinking as not the kind of thinking in which one just receives ideas, knowledge, and information from someone else. As opposed to being passive, the active process in critical thinking requires individuals to think things through, raise questions, and find relevant information by themselves. This view integrates critical thinking with the element of reasoning in one's thinking process. Accordingly, Fisher (2002) describes critical thinking as an active process in which a person thinks and

raises questions independently while persistently uses relevant information to develop a logical conclusion.

The concept of reasoning has additionally been emphasized in her views when she claims that reasoning shapes one's beliefs about particular issues or subjects due to the critical thinking process. Based on the above definition, she recommends few important and fundamental skills in critical thinking which include identify the elements in a reasoned case especially its reasons and conclusions, identify and evaluate assumptions, clarify and interpret expression and ideas, judge the acceptability especially the credibility of claims, evaluate arguments of different kinds, analyze, evaluate, and produce explanations, analyze, evaluate, and make decisions, draw inferences, as well as produce arguments. An expert in Cognitive Psychology, Diane F. Halpern, interprets the term critical thinking as;

> "The use cognitive skills or strategies that increase the probability of a desirable outcome." (Halpern, 1998b, p. 450)

Each individual might produce various desirable outcomes such as the choice of different careers in their lives. This particular outcome is a goal that a person needs to achieve which is also purposeful, directive kind of thinking. It is not prompt and usually used with conscious intention in many settings. Additionally, in distinguishing between wisdom and other types of thinking, Halpern says;

> "The term critical thinking is the use of those cognitive skills or strategies that increases the probability of a desirable outcome. It is purposeful, reasoned, and goal directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. Critical thinkers use these skills appropriately, without prompting, and usually with conscious intent, in a variety of settings. That is, they are predisposed to think critically. When we think critically, we are evaluating the outcomes of our thought processes – how good a decision is or how well a problem is solved. Critical thinking also involves evaluating the thinking process – the reasoning that went into the conclusion we have arrived at or

> the kinds of factors considered in making a decision." (Halpern, 2001, p. 254)

In the definition above, Halpern clearly illustrates her views on what it means by thinking critically. It begins with a goal or mission that a person needs to achieve, for example in solving a problem or making a decision in career choice. With appropriate cognitive skills and relevant strategies, that person is predisposed to think critically. Every strength and limitation of a decision is weighted wisely so that the desirable outcome is achievable.

Figure 2.1: Halpern's working on the definition of critical thinking (Halpern, 2001)

Other than that, Halpern perceives critical thinking as an element of higher order thinking which requires the right utilization of advanced cognitive skills within human mind. This type of skills is relatively more complex in comparison to that of lower order thinking. It requires judgment, analysis, and synthesis of a wide range of thoughts, opinions and ideas, as well as not being applied in a simple and mechanistic manner (Halpern, 1998a). This illustration also reflects our daily lives because life itself is complex, messy, and deals with ill-defined problems. In this case, Halpern (1999) agrees with Elder and Paul (2010) by arguing;

> "Although there are many versions on the definition of critical thinking, all of these approaches share a set of common assumptions; there are identifiable critical thinking skills that can be taught and learned, and when

> students learns these skills and apply them appropriately, they become better thinkers." (Halpern, 1999, p. 70)

Next, critical thinking has become one of the primary objectives in the policy of education of any learning institution for decades (Hatcher, 2006). Schools and colleges are obliged to design appropriate course structure to develop this skill therefore consensus understanding on the definition of critical thinking is needed for this matter. In this case, a qualitative study known as the Delphi Method has been conducted by the American Philosophical Association (APA) in 1988 until 1989 to come up with a standard definition of critical thinking. Forty-six experts who are highly experienced in this field have agreed that;

> "Critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. Critical thinking is essential as a tool of inquiry. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal. It combines developing critical thinking skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society." (Facione, 1990b, p. 3)

In the definition, experts have come to agreement that critical thinking is purposeful thinking that requires the use of highly valuable cognitive skills. These skills are applied in the sense that a person has to be inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results (Facione, 1990b).

Contending on the process of thinking, Facione (1990b) also views critical thinking as a circular process, not simple, and not a linear one (Emir, 2013). This is due to complex and ill-defined problems or issues that a person has to deal in his daily life. The term circular signifies that reflection activities in thinking always occur in a person's mind to recheck and reassess his decision to an issue.

2.2 Critical thinking skill tests

There are many versions of critical thinking skills test. Researcher needs to choose the one that meets the requirement to answer research questions of a research. This is because different type of assessment would yields different result. Moreover, different assessment can only be used onto different type of sampling based on age, level of education, gender, etc.

Celone (2001) for example used Test of Non-Verbal Intelligence – Third Edition (TONI-3) to test level of abstract reasoning and problem solving skills among school children. Participants used in the study were school children ranging between 7 years old to 14 years old. Results of the study demonstrated different level of abstract reasoning possess by participant. McDonald (2017) investigates a method of enhancing critical thinking through a problem-solving game called the Coffee Shop, an entrepreneurial problem-solving game. Participants were secondary school students aged 13 to 14 years old from a Cambridge International Examination IGCSE Business Studies course. The pre-test and post-test for this study was developed by researcher to suits with participants' business background of study.

For this study, the California Critical Thinking Skills Test (CCTST) was used based on the elements it comprises; critical thinking skill elements such as inference,

inductive reasoning, deductive reasoning, etc that appropriate to assess the effectiveness of chess on participants. Moreover, the assessment is designed for elementary school children with average intelligent, which matched with the profile of participants in this study.

In addition to that, level of questions asked in the assessment is appropriate with students' level of understanding and education based on the results of pilot study that has been conducted prior to this study.

2.3 The California Critical Thinking Skill Test (CCTST) for elementary school children

In the educational setting, new pedagogical approaches are tested for their effectiveness. In this research, chess instruction module was tested for its effectiveness to develop participants' critical thinking skill through a standardized test. The standardized test was the California Critical Thinking Skills Test (CCTST). The CCTST is constructed based on the Delphi Expert Consensus Definition of Critical Thinking which involved forty-six widely recognized professionals who have special experiences and are experts in critical thinking instruction, assessment, or theory. It was a two-year project conducted to construct the definition of critical thinking and its sub skills, identify the characteristics of a critical thinker, and also recommend specific instruction and assessment for critical thinking.

Concordance with the consensus understanding of critical thinking, the test instrument used for this study measures seven cognitive skills of critical thinking; analysis, interpretation, inference, evaluation, explanation, deductive reasoning, and

inductive reasoning (Facione, Facione, and Winterhalter, 2011). Table 2.1 shows the description of each skill.

Table 2.1: Critical thinking skills description

SKILL	SUB-SKILL	DESCRIPTION
Analysis	Examining ideas Detecting arguments Analyzing arguments	To closely examine ideas, to identify assumptions, reasons and claims, as well as to gather detailed information from charts, graphs, diagrams, paragraphs, et cetera. Precision is the key to analysis. It would be unwise to build further judgments, such as inferences and evaluations, upon the results of a poor analysis.
Interpretation	Categorization Decoding significance Clarifying meaning	To determine the precise meaning of a sentence, passage, text, idea, assertion, sign, graph, diagram, signal or chart in a given context and for a given purpose. Interpretation often involves categorizing information, decoding the significance of what a person is saying, and clarifying what something means.
Inference	Querying evidence Conjecturing alternatives Drawing conclusions	To draw conclusions based on reasons and evidence. Inferences could be skillfully drawn from a wide variety of things including information, data, beliefs, opinions, facts, conjectures, definitions, principles, images, signs, behaviors, documents, or testimony. However, skillful inference does not guarantee that the conclusion would be true. Conclusion inferred on the basis of misunderstandings, mistaken beliefs, bad data, unreliable opinions, biased evaluations, or faulty information. For example, faulty information could turn out to be mistaken, although if it is reached using excellent inference skills.
Evaluation	Assessing claims Assessing arguments	To assess the credibility of claims and the strength or weakness of arguments. Evaluation skills can also be applied to form judgments about the quality of inferences, analyses, interpretations, explanations, options, opinions, beliefs, ideas, beliefs, and justifications.

Table 2.1, continued:

SKILL	SUB-SKILL	DESCRIPTION
Explanation	Stating results Justifying procedures Presenting arguments	To provide one's reasons, methods, assumptions, or rationale for one's beliefs and conclusions. Reaching a correct conclusion is not sufficient for a strong foundation of critical thinking. Strong critical thinking involves reaching a correct conclusion for a good reason, not by luck on or the basis of weak arguments and mistaken opinions.
Deductive reasoning		Deductive reasoning moves from the assumed truth of a set of beliefs or premises to a conclusion which follows of necessity. In a valid deductive argument, the conclusion could not possibly be false if the premises are all true. Geometry, algebra, and many computer programs are deductive chains of reasoning, such as Sudoku puzzle. Activities which require following rules, definitions, laws, or diagrams with exacting precision call on deductive reasoning skills.
Inductive reasoning		Inductive reasoning is drawing warranted probabilistic inferences regarding what is most likely true or most likely not true, given the information and the context at hand. Scientific disconfirmation of hypotheses uses inductive reasoning. Drawing probabilistic conclusions based on key examples, evidence, data, precedents, memories, testimony, or relevant cases is inductive. Reasoning by analogy is inductive. As long as there is the possibility, however remote, that one's highly probable conclusion might be mistaken, one is using inductive reasoning.

Facione et al. (2011) and Facione (1990c).

2.4 The needs to develop critical thinking skill

There are many concerns that have been raised in discussing about developing critical thinking skill among school students such as method of teaching, content of

curriculum, as well as assessment or evaluation method that could be used to measure critical thinking. Since 1990s, many researches and programs have been implemented in Malaysia to enhance critical and creative thinking skills in schools, but despite of that, it is found that those initiatives have failed to provide adequate knowledge and skill to teachers pertaining to critical and creative thinking skills (Rosnani, 2009). Research by *Akademi Kepimpinan Pengajian Tinggi* (AKEPT) indicate that 50% of teachers failed to deliver their lessons effectively and showed inability to inculcate Higher Order Thinking Skills (HOTS) in their teachings (Nor'ain & Chinnappan 2016). Higher Order Thinking Skills (HOTS) include: logical thinking, critical thinking, and reasoning skills. These are also the basic skills of daily life, not only important in the academics.

Following the review of literature, there are three different perspectives which would be highlighted with regards to tackling the issue; the importance of critical thinking skill in academic, career and life.

2.4.1 The importance of critical thinking skill in academic

In every level of education, students are loaded with massive amount of information that require them to apply the right and relevant types of cognitive skills such as creative, critical, analytical, and problem solving skills. Students who are dealing with various issues, problems, or case scenarios that need to be solved effectively must carefully evaluate, analyze, and synthesize the sources of information being presented regardless of whether those issues are related to their studies or personal lives. In most cases, students merely practice rote learning that is by memorizing theories and facts that they learn at their schools.

In return, students are not able to adapt and apply the academic concepts into realities by producing something new or making innovations on existing ideas available in any discipline of knowledge. Therefore, the need for integrating the element of critical thinking skill at school has long been accentuated in developed nations especially the United States. This is seen through its nearly 300 years of experience in school policy-making that promotes eight broad goals of schooling which are basic academic skills, critical thinking and problem solving, social skills and work ethics, citizenship, physical health, emotional health, arts and literature, and finally the preparation for skilled employment.

Critical thinking has become the focus of national education system throughout the world and desperately needed in education especially in the late twentieth century by infusing critical thinking skills in school and university subjects (Marples, 2002). The aspiration is stated in the National Institute of Education Report in 1984, 'Involvement in Learning: Realizing the Potential of American Higher Education' which recommends that the curriculum should ensure the development of students' analytical, problem solving, communication, and synthesis skills (McMillan, 1987). Students are hopefully able to adapt to a rapidly changing world that requires them to think critically and to synthesis large quantities of information.

Singapore, as one of Malaysia neighbor country, and ranked high in TIMSS and PISA, really push their teachers and students to master their HOTS. There have been several initiatives by the government, and one of them is through their "Teach Less, Learn More" (TLLM) national education policy.

It is said that:-

> "…schools should have less dependence on rote learning, repetitive tests and a 'one size fits all' type of instruction, and more on engaged

> learning, discovery through experiences, differentiated teaching, the learning of life-long skills, and the building of character through innovative and effective teaching approaches and strategies" (Koh et. al, 2012, p.137).

It can be concluded that it is a process to transform passive learning to engage learning amongst students. Learners are proactive agents, while teachers are facilitator. Learners should be responsible for their own learning; strategic in their learning process; collaborative with others; and energized throughout the learning process (Koh et.al, 2012).

2.4.2 The importance of critical thinking skill in career

Throughout one's career, he would be presented with a variety of information in many different types of situations. A manager at workplace, for example, needs to be involved in solving or overcoming any problem or issue faced by his team members by comprehending, interpreting, and analyzing the best action plan or execute the most suitable strategy available. He might have to identify the existing strengths and weaknesses within the internal business environment before weighing them against the opportunities and threats available within the external business environment.

He is required to make the right decisions in all circumstances by taking into consideration the political, economic, social, technology, and many other issues. The author of 'Experimental learning to see through strategic behavior in large scale projects' categorizes problems at the workplace in two categories which are structured and non-structured. The structured problems are problems with documented solutions in software or database at the workplace. These problems do not require complex problem solving process as it has occurred previously. Through one's experience and data available, problems could be solved in a nick of time (Bowman, 2008). The non-

structured problems, on the other hand, are the problems with solutions which have not been documented and discovered before.

For instance, a new bug in computer software would create great deals of modification of data because programmer does not anticipate such things to happen and no documentation about it being prepared based on previous experience. This type of problem is the main reason why employers are seeking for good problem solvers to be hired rather than graduates who pass their exams due to their outstanding memorizing skill. To do this, most employers nowadays use what is called as Aptitude Test to filter their candidates. This is an assessment tool for thinking skills which present questions for various case scenarios or problem based learning pertaining to workplace. It requires candidates to think through about problems presented, interpret the situation, analyze the judgments made, and make an inference on what to do to solve the problems.

2.4.3 The importance of critical thinking skill in life

In life, a person deals with great numbers of problems for example choosing the right courses at the university, choosing a good car to buy, choosing the right partner to marry, and choosing the right leader for the country, among others. There are a lot of decisions need to be made throughout one's life. In this case, the acquirement of critical thinking skill has become the national priority in the United States of America, urging researchers to produce various critical thinking assessments for every level of age. The Congress has established the assessment of critical thinking as a national priority in the Goals 2000: Educate America Act by the Department of Education that states;

> "In 1990 President Bush, in concert with the governors of the 50 states, preeminent among them being Governor Clinton, articulated five national educational goals. Goal 5 states that adult Americans will possess the knowledge and skills necessary to compete in the global economy and

> exercise the rights and responsibilities of citizenship. To achieve this, the proportion of college graduates who demonstrate an advanced ability to think critically, communicate effectively, and solve problems will increase substantially." (Taube, 1997, p. 129)

The Congress argues that critical thinking is a skill which all Americans must acquire and therefore the effort to enhance the skill needs to become a priority in the national agenda. Critical thinking skill which includes the actions of interpretation, analysis, evaluation, deduction, induction, inference, and self-regulation would help a person to avoid making foolish decision. The solution or decision made by a critical thinker is usually free from any unwarranted pre-assumption and bias (Taube, 1997). Additionally, Pollock (2004) also links the deficits in problem solving skills with suicidal behavior in a person which he refers as 'passive problem solver'. In his study, two groups of subjects had been selected which were suicide attempter group and non-suicidal psychiatric control group.

Pre-test and post- measures were administered shortly after admission and later, after six weeks. The analysis measures depression, hopelessness, suicidal ideation, and social problem solving ability. The result showed that the suicide attempter displays poorer problem solving ability as compared to the control group (Pollock, 2004). On the other hand, together with the technical skills that are necessary to be applied during playing chess, Van Der Maas & Wagenmakers (2005) believes that lesson about success and failure is far more important for its players to improve their critical and problem solving skills.

2.5 History of chess: an overview

In the next discussion, we would look through the history of chess; how chess has survived throughout centuries passing different cultures and communities, as well as how it brings significant meanings to various parts of the world.

Based on earlier evidence of literature, chess is believed to have existed in human civilization since the middle of sixth century A.D. (MacDonell, 1898; Gamer, 1954; Levitt, 1991). The game was initially called 'caturanga' and played only by the king and his members of the clan in India. Caturanga is a Sanskrit word that frequently appears in two great Indian epics, the Mahabharata and the Ramayana (MacDonnel, 1898).

There are several interpretations on the meaning of the word 'caturanga'. First of all, it is described as an adjective, having four (catur) limbs (anga). Sometimes, it is being described as a noun, which means 'four-membered'. This word also refers to four parts of regular Indian army which is believed to have been formed as early as the fourth century B.C. (MacDonnell, 1898). The four parts consist of four members of army which are elephants, chariots, horses, and infantry. Other interpretation is that 'having four limbs' refers to the fifth piece of the game, which is the king.

It is the king who has four limbs, a complete army, and who rolls the dice in the game. Dice is used as part of the game at that time (Levitt, 1991). In this game, the player is the regarded as the king of his own kingdom, which explains why this game is called 'chess' which means king, derived from the Persian word of 'shah'. Next, another version of the meaning of 'caturanga' is that it refers to the universe conceived as a cosmic man having four limbs (Levitt, 1991). The cosmic man is Brahman, an Indian

God. The four limbs represent common man on the bottom of Indian social order, also known as ‘infantrymen’ or ‘footmen’. On the top of the order there is ‘elephant’ as a symbol of wisdom called Brahman.

The other characters are in between elephant and footmen. This most intellectual game of centuries (MacDonell, 1898) carries different names as it enters different parts and phases of world’s history. Chess entered the Persian world through Persian king Khusraw I Anushirwan in the seventh century. The game then changed its name to ‘catrang’ which brings the same meaning as in the Indian version (Bland, 1852; MacDonell, 1898). Next, when the Arabs conquered Persia in the seventh century, the game was introduced to the Middle East, Spain, and Byzantium. It was then called as ‘shatranj’, also brought the same meaning as ‘caturanga’ (Levitt, 1991).

The game then spread to Italy and then to the other parts of Western Europe. From Middle East, the game then again spread to China through trade route between them. The word ‘shah’ emerged later, referring to the principle piece of Persian’s game; the king which means ‘shah’ (Gamer, 1954). This term was also used by the Arabs. It was later in the European civilization when the word ‘shah’ changed to ‘chess’ as what we call the game today. The modification in the names happens phonetically with no etymological difference. Just like the changes in the name of the game, some pieces also have different names across various cultures. For instance, the ‘minister’ or ‘general’ in the Middle East is called as ‘queen’ in Europe. The ‘elephant’ or ‘camel’ in the Middle East is referred as ‘fool’ in France or ‘bishop’ in England while the ‘horse’ in the Middle East is ‘knight’ in Europe (Levitt, 1991).

Besides the history of its name, it is believed that chess was initially played by four players in India with each army made up of eight pieces (Levitt, 1991). It was also said that the game was a four-player game, but played by only two persons, in which each player has two hands, thus representing two players. It is reasonable to conclude that chess is a famous and sustainable game throughout the history of mankind in various parts of world. It has been played for more than 1500 years since its existence. Although chess has its very own distinctive names in different civilizations, the concept of the game remains the same. It is the game of war which requires strategic and analytical thinking skills to be successfully played. Chess is also culturally independent.

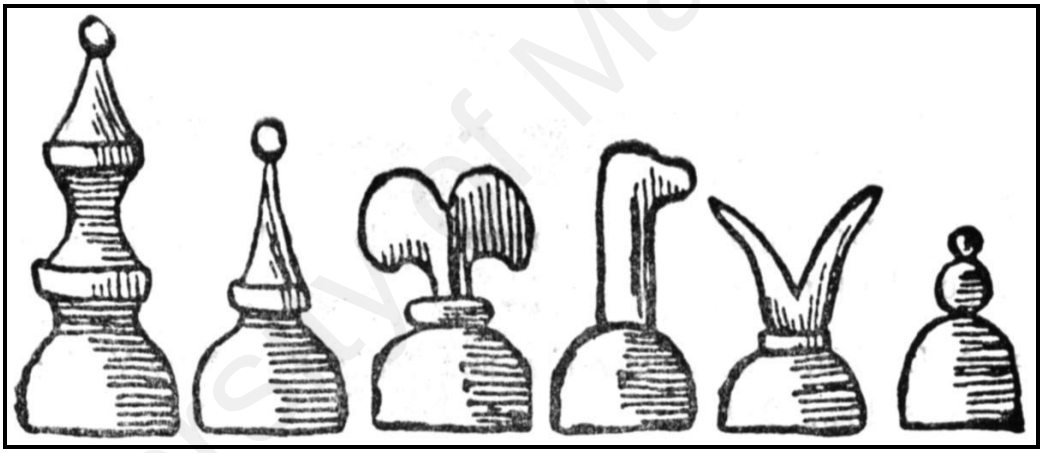

Figure 2.2: English chessmen from the time of Caxton in the 15th century (Gamer, 1954)

Chess has also survived through different cultures and historical contexts, but knowledge of the game is conceded through Indian civilization to Persian culture, then to huge parts of Middle East and Western Europe, before finally reaching China with the same concept and meaning; the four divisions of army. This shows that the language of chess is independent. In an article entitled *'The Moral of Chess'* released by The Columbian Magazine in 1786 which was written by America's famous philosopher, Benjamin Franklin (as cited in Berkman, 2004), he stated that chess is more than just a

game; it teaches players to become foresight, circumspection, and cautious of their actions.

2.6 The role of chess in facilitating learning at school

The game of chess has been proven to be a good learning aid in developing students' thinking abilities especially in the aspect of their problem solving skills (Grant, 1993). Several studies have been conducted to explore the role of chess and its impacts on mathematics score (Berkman, 2004; Barrett, 2010) while other researches examine the relationship between chess and non-verbal learning performance (Pearson, 2008). There are also studies that focus on chess and its ability to develop business skills and problem solving skills (Anonymous, 2002; Graber, 2007). One of the findings states that with chess, educators would be able to reach students' minds with fun and challenging nature of the game.

Just as chess has not been confined to any particular age, race, country, or class (Cleveland, 1907), the game itself is widely known for its status in the working of memory construction, pattern recognition, and non-verbal reasoning (De Groot, 1978; Puddephatt, 2003). These are generic skills found in the game and it is applicable across variety of subject domains. This is also the main reason why chess is said to have huge impacts on the development of creative domains such as music, mathematics, and of course thinking and reasoning (Goldin, 1979; Rifner, 1992; Hong, 2005; Pearson, 2008; Barrett, 2010). The following section would discuss about related literatures or studies that have investigated any significant connection between chess and the aforementioned variables in creative field.

2.6.1 Chess and mathematics

Chess brings many qualities in mathematics education for example it enhances the motivation of an individual in solving mathematical problems, the satisfaction feeling of accomplishment, as well as the interesting elements of multiple rules and strategies that could be applied in a particular lesson. Chess also helps to improve concentration and the creative aspect of a person for example chess players have the capability to see patterns in geometric questions. In this section of literature review, the analysis of the impacts of chess on mathematics as a subject at every level of education would be thoroughly discussed. In 1975, Whitman used chess to teach geometry in classroom. At that time, the teaching was based on the Euclidean geometry which today is viewed as deduction system.

It was also based on the viewpoint that geometry is an abstraction of metaphysical environment. In this attempt, lesson started with the students got their pairs according to their level of knowledge in chess; those who knew how to play chess were paired with those who did not know. They were given a short briefing about the introduction to laboratory activities in the classroom and were asked to read and study the instructions, rules, and strategies of chess. After several days, when the students were getting more comfortable with the game, the classroom, and their friends who were now their pairs, a quiz was administered to test their knowledge of the game and as a prelude to another lesson on geometry.

These are the questions given in the quiz session (Whitman, 1975):

1. Name the things or materials you need to play chess.
2. State two rules in the game of chess
3. Why is the following rule in the game of chess true; '*white always moves first*"?
4. In order to play chess, name one item that you need to memorize.
5. What is the objective of the game of chess?

The quiz is helpful to show the analogy between the game of chess and the game of geometry. It gives an impression that just like chess, geometry is a fun subject to learn and play with. This is followed by explanation on the analogy between chess and geometry as shown in Figure 2.3. Whitman (1975) believes that by discussing the analogy between chess and geometry, students would be able to start their lesson in a more systematic way and are not afraid of to learn geometry. They would be thinking that geometry resembles the elements, rules, and strategies of chess.

Chess	Geometry
Chessboard, kings, queens, rooks, bishops, knights, and pawns.	Called elements like points, lines and planes.
Rules tell how pieces are related.	Rules tell how elements are related.
Rules are accepted as true. There should be no attempt to explain why.	Rules (axioms or postulates) are accepted as true. There should be no attempt to explain why.
Tricks are used to remember rules. For example to remember how knights move, players would say a knight moves in 'L' shape.	Pictures and other physical objects are used to help learners remember related concepts.
Its main objective is to 'checkmate' the opponent's king.	Its main objective is to determine if the statements at the beginning are true or false. Realization of the objectives has consequences for mankind.

Figure 2.3: The analogy between chess and geometry (Whitman, 1975).

In addition to that, chess also offers a great platform for students to learn concepts of mathematics more effectively as shown in the Venn diagram in Figure 2.4. Students would genuinely enjoy the activity of creating puzzles with chess pieces that they share with their classmates (Berkman, 2004).

Furthermore, Berkman (2004) argues that chess is much the same as mathematics in a way that the activity of evaluation, outcomes prediction or pre-assumptions, and steps planning are a continuous process for chess players in order for them to win the game. This is similar to finding solutions in the case of mathematics (Berkman, 2004).

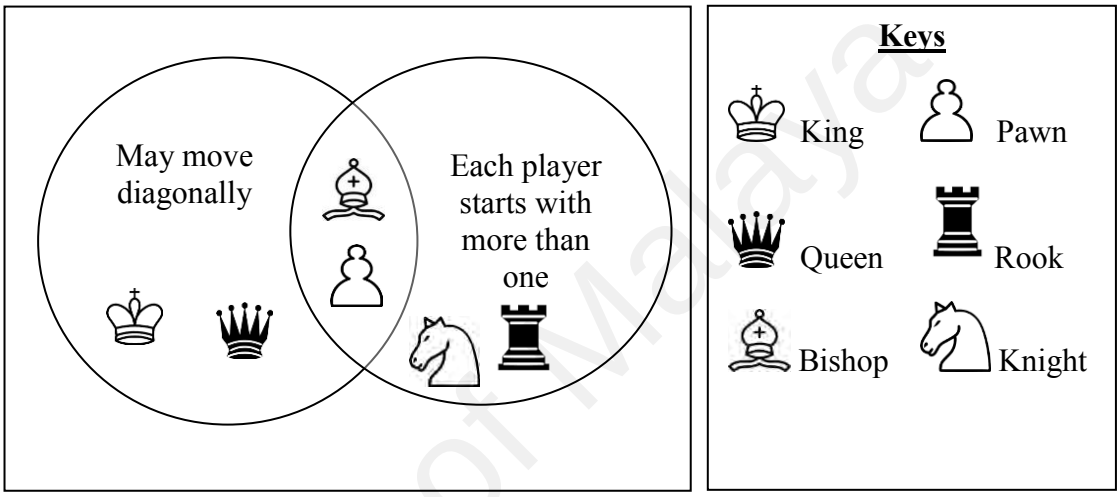

Figure 2.4: The relationship between chess pieces is shown in Venn diagram (Berkman, 2004).

With all the qualities discussed, unlike any other games, chess offers simultaneous benefits to the players. It is a game that promotes higher order thinking particularly in the aspects of strategic management and problem solving skills. At the same time, it helps students to polish their skills in mathematics at school.

2.6.2 Chess facilitates the teaching and learning process of science

As far as the research on chess is concerned, more research is needed to see the direct connection between playing chess and students' performance in science subject. Some of the researches found were investigating the way chess enhances memory, verbal reasoning, critical thinking, and problem solving skills (Rifner, 1992; Celone, 2001; Hong, 2005; Atherton, 2007; Pearson, 2008). These are the important elements in

learning science. Just like in the game of chess, good memory span is required in science subject as students are dealing with complex structures and need to keep large numbers of information while at the same time solving problems at hand (Khan, 2000).

This aspect is clearly emphasized in Pedlar's research on memory and science (Pedlar, 2007). Additionally, a psychometric analysis of chess expertise was carried out by Professor Han L. J. Van Der Mass in 1998 during the Open Dutch Championship in Dieren, Netherlands using an internationally valid chess test instrument, the Amsterdam Chess Test (ACT). In the analysis, several hypotheses about the relationship between chess expertise, chess knowledge, motivation, and memory were tested (Van Der Maas and Wagenmakers, 2005). Out of 259 participants with Elo rating (an internationally recognized chess rating system), only 234 participants completed the entire ACT, which took about an hour to be completed.

Six subtests given in the ACT were; (1) the choose-a-move test part A, (2) the motivation questionnaire, (3) the predict-a-move test, (4) the verbal knowledge questionnaire, (5) the recall test, and (6) the choose-a-move test part B. The fifth test was related to chess-memory hypotheses. Findings showed that experts' results were superior to that of novices even when random positions were used. This result supports Gobet and Simon (1996) who argue against the statement made by Simon and Chase (1973) that the superiority of experts disappear when random positions are used (Van Der Maas and Wagenmakers, 2005).

This study has also proven that the level of memory span would increase over time spent in the game of chess; the more rounds of game you play, the more positions you would likely to remember. Besides increasing the memory span, chess, according to

Warren (1917) provides scenario-based learning environment to children just like learning science. The game creates a vast number of scenarios through positions of its pieces. Players have to think deeply and reflect the consequences of each move whenever they want to move their pieces. Figure 2.7 shows one of scenarios that might occur when they play chess.

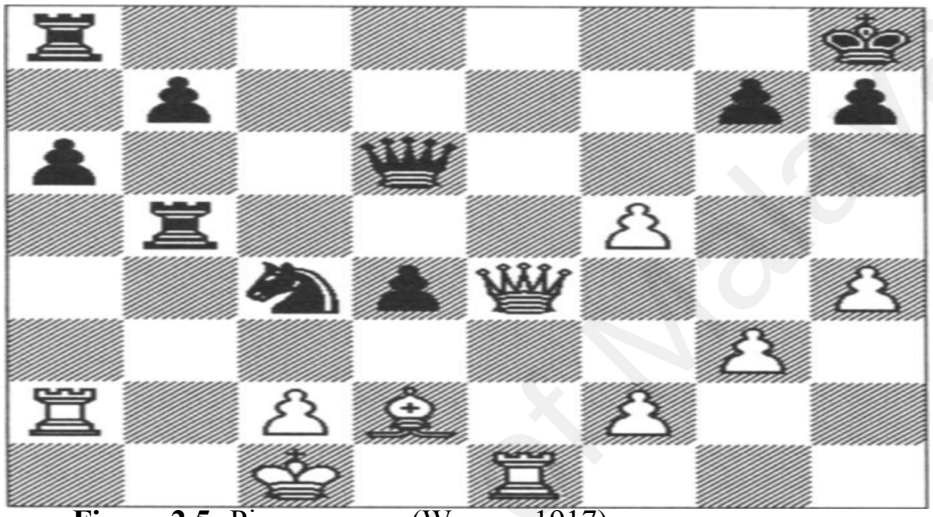

Figure 2.5: Pieces moves (Warren, 1917).

As shown in Figure 2.5, players need to thoroughly think all the consequences that might occur before they move their pieces. In the example, the best strategy for the game is to move A2 to A6. If the player move E4 to X0, this means that the Queen is accidentally dropped outside the board. Also if he move B4 to D2 and D4 to C2, they are all illegal moves.

The scenario-based or problem-based learning has been implemented in many science subjects including clinical courses offered in colleges. This approach requires instructors and students to be active participants. Two studies on science and learning have examined problem-based learning as a dynamic pedagogy that promotes real-life problem solving skills. Both studies found significant effects of the approach in

comparison to traditional lecture method (Seon & Mi, 2006; Tiwari et al., 2006). Other than that, Wong et al. (2008a) examines the effects of problem-based learning in a simulated clinical setting. It was the second phase of a study that was conducted with the objective to develop students' professional competencies in handling real-life cases.

The first phase of the study aims at educating instructors on conducting problem-based learning in clinical setting and understanding experiences of students and instructors after the problem-based learning intervention in clinical setting (Wong et al., 2008a). Third year students from undergraduate nursing program were selected for this study. Series of problem-based learning approach were videotaped and transcribed for analysis. The data analysis used the strategy of conversation analysis proposed by Silverman in 2001. He suggested three rules to guide the analysis which are to identify the sequences of related talk, to examine how speakers take on certain roles or identities through their talk, and to look for particular outcomes of the talk (Wong, et al., 2008b).

The study discovered successful experience of adopting problem-based learning in clinical setting as there were dynamic conversations going on between students, patients, and instructors. Wong, et al., (2008b) proves that problem-based learning approach enhances problem solving skills in science. Problem solving skills are generic skills that could be transferred across domains or subjects (Rifner, 1992) and it is believed that chess provides good platform to enhance the skills (Adams, 2012). Next, Celone (2001) conducted a study examining the effects of chess program on abstract reasoning and problem solving skills among elementary school children. Nineteen elementary school children ranging between 7 years old to 14 years old were self-selected for one week chess program consisting of 20 hours of instructions.

Next, pre-test and post-test were given using the Test of Non-Verbal Intelligence – Third Edition (TONI-3) and the observation on Knight's Tour in the game made by participants simultaneously; a sequence of moves of a knight on a chessboard such that the knight visits every square only once. These were the chess problem instruments being used to administer the participants. Results from this study showed a significant increase in the levels of abstract reasoning and problem solving skills among school children. Also, a significantly positive correlation was discovered between the TONI-3 instrument and students' academic achievement at school.

This phenomena, according to Celone (2001) indicates that chess promotes academic success. Rifner (1992) has also conducted a study to investigate the transfer of problem solving skills among students with two different levels of intelligence which are average and above average. His research subject was divided into four groups which were gifted students (chess group), gifted students (non-chess group), average students (chess group), and average students (non-chess group). The study evaluated six aspects of students' problem solving attitudes; 1) the number of problem-solving methods that students applied, 2) the number of lines being considered in arriving at a particular solution, 3) the number of goals that students set as they solved the problem, 4) the percentage of those goals which were achieved, 5) the number of guesses the students made in relation to the number of statements of hypotheses or solutions, and 6) the percentage of negative evaluations (Rifner, 1992).

Finally, in this particular research, Rifner (1992) concluded that 'gifted students' who also attended chess classes were the most outstanding and best problem solvers as compared to other students in the remaining three groups. Meanwhile, the 'average students' who took chess classes were able to apply more problem solving methods but

easily got confused when attempting to answer more complex questions. Students in general decided to reduce their confusion in learning by defining fewer goals, narrowing the scope of knowledge, and guessing more answers.

2.6.3 Chess enhances critical thinking skill

In order to conform to the No Child Left Behind (NCLB) in the Elementary and Secondary Education Act of the United States of America, public schools are forced to develop programs that focus on developing students' mathematics and reading skills (Ong, 2008). Critical thinking skill is also included in the program and for that matter, chess has been used in elementary schools nationwide to cope with these needs. This is because chess provides a good platform for students to learn related subjects like History, Mathematics, Science, and some important elements in thinking skill as they play and learn the strategies of the game. This program is called First Move. In addition to that, chess program with its main objective to encourage students to become effective problem solvers in their lives is sponsored by one of the world's chess champions who also holds the title of Grandmaster at the age of thirteen, Magnus Carlsen.

Carlsen recently announced his partnership with America's Foundation for Chess with initial grant of one million dollar to bring the First Move program to half a million students by 2017 (First Move, 2014). As a Grandmaster, he believes that chess empowers kids to become critical thinkers. The program currently reaches over 80,000 students in 24 states and four countries. On that note, the effort to enhance children's thinking skills has started as early as in the 1970's. A four-year project (1979-1983) was conducted by Ferguson (n.d.) on grade seven to grade nine students in the area of Bradford, Pennsylvania to enhance students' reasoning using chess. The project was called EXPLORE program which used variety of special activities including chess,

Dungeons and Dragons, Olympics of the Mind, problem solving with computers, creative writing, independent study, et cetera. (Ferguson, n.d.).

In this project, experiment group followed chess instructions while subjects in the control group chose their own activities other than chess. The result showed that chess exceeded other thinking development programs and activities in enhancing students' reasoning skill. On the other hand, in 1995, Robert Ferguson conducted a five-year study at a school in Pennsylvania district among grade seven and grade eight students who participated in chess classes. Ferguson used the Watson-Glaser Critical Thinking Appraisal to assess the thinking skills of children. The results of the study showed that children who regularly involved in chess classes improved their scores on the Watson-Glaser Critical Thinking Appraisal by 17.3 percent.

Other subjects that participated in other enrichment activities such as problem solving computer programs, Dungeons and Dragons, and creative writing, improved their scores by 4.56 percent (Ferguson, 1995). In this case, Ferguson's study demonstrated that chess is efficient in improving critical thinking skill more than other enrichment activities that the children participated in. Besides that, Gliga and Flesner (2014) experimented chess instruction on novice children. These were the children who never played chess before. Participants were assessed using their performances in Mathematics and Romanian Language subjects called School Performance Test (SPT), assessment on focused or sustained attention and resistance to monotony called Kraepelin Test, verbal memory test called Rey Test, and the assessment to discover the clinical insight into children's cognitive functioning extracted from the digit span subtest Wechsler Intelligence Scale for Children (WISC) (Gliga & Flesner, 2014).

Participants' performances during pre-test and post-test were then analyzed and the result showed that students from chess group significantly improved in their SPT and possessed higher intelligent quotient to that of the students in the control group. Following the literature, it could be clearly seen that a significant amount of efforts to enhance children's critical thinking skills have been going on since 1970's through school and national programs across many countries in the world, especially in the United States of America and few other developed and developing European countries. Endorsements from school and university's grants have placed a guarantee upon the continuity of the accomplishment of these efforts.

2.6.4 Chess and music

Chess is said to have played a significant role in the life of many prominent and legendary composers or music organists, among others are four British organists namely Sir Hubert Parry, Professor Prout, Sir Walter Parratt and Dr. A. L. Peace (Mansfield, 1928). Some of them treated chess as a necessary element in balancing their works in composing music. Suffice to say that perhaps chess has created the habits of mind in which those organists need to solve problems in music composing, just as problems they face in the game of chess. According to Fine (1944), chess is much the same as music in which both areas are efficient in cultivating critical and creative thinking, absorbing mental pursuit, as well as both could be played for hours sometimes days and the enjoyment never ceased.

Furthermore, the most outstanding element that a chess player must have is a fertile imagination. He must be able to detach himself from the real world and dive into the world of shapes and forms to really understand the essence of the game including the mastery of chess strategies. Likewise, this character also presents in most music

organist (Fine, 1944). Accordingly, the arguments indicate that abstract reasoning, a generally accepted quality inherent in both mathematics and music, is of prime importance in chess. In the twentieth century, many educators, parents, and chess experts maintain that chess education improves a host of mental abilities including abstract reasoning and problem solving (Rifner, 1992).

2.7 Chess enhances other spatial skills pertaining to learning

Many schools throughout the United States of America and Canada have established quite a number of chess programs to help children develop chess skills that would help them in other areas of their academic careers. There are several studies to support the improvements made in different areas of academic. A study by Frank cited in Zaire (1973; 1974) showed that students demonstrated marked development of numerical and verbal aptitudes after one year of chess instruction (Ferguson, 1995). In 1991, Margulies performed a study on the effects of chess on reading scores in a New York City chess program in District 9 of the Bronx. In that study, chess players outscored average students in the district and the country in reading scores after two years of chess instruction.

Next, many schools all over the world encourage students to play chess to enhance their academic performances (Margulies, 1991). Students' IQ and examination scores have also proven to be improving after students are exposed and being educated with the game of chess, together with their mathematical, language, and reading skills (Dullea, 1982; Palm, 1990; Margulies, 1991; Ferguson, 1995; Liptrap, 1998). Additionally, chess has even become a fun way to teach children how to think and solve the ever-changing and diverse arrays of difficult and complicated problems (Whitman, 1975; Van Der Maas & Wagenmakers, 2005). More and more schools around the world

are recognizing the value of chess, with chess instruction now becoming part of standard curriculums. Some researchers believe that reasoning is the core characteristic in playing chess, in which inductive and deductive reasoning could both be present in the game (Ferguson, 1995; Brandefine, 2005).

On the other note, Graham (1985) believes that playing chess involves abstract reasoning, analysis, judgement, and recall. Children tend to break down big problems to smaller pieces and then put them back all together. As Vail (1995) points out, chess has a rare quality where children tend to enjoy the game and later understand that it is something good for them as well. Chess could also inherit an aesthetic appeal to the children playing the game. It is not only used to polish children's thinking skills but also has turned out to become very interesting and attractive for students in other levels of education as well (Vail, 1995). Ferguson (1995) further encapsulates different findings on the effects of chess on children. He believes that chess accommodates all modality strengths and provides a great quantity of problem solving solutions in reality. Chess also has an immediate punishment and reward system for problem solving as well as a thinking system pattern that when is being used faithfully leads to success.

There is also the competition factor in the game of chess which promotes alertness, challenges students' minds and attitudes, and brings out the highest levels of achievement. He further emphasizes that a learning environment revolving around games has a positive effect on students' attitudes toward learning. This effective dimension acts as a facilitator of cognitive achievement, and instructional gaming is one of the most motivational tools in good teacher's repertoire. Naturally, children love games and chess could be a tool to motivate them to become good problem solvers who are willing to spend hours immersing in logical thinking. This is the same condition for

young people who could not sit in a traditional classroom environment; they now enjoy thinking vigorously on how to play with their opponent. Finally, he argues that chess supplies various qualities of different problem solving solutions (Ferguson, 1995).

2.8 Conclusion

It is widely argued that chess has the potential in enhancing students' capability of learning; whether in music, science or mathematics. This is due to the characteristics of chess that comprises of many elements or skills that are useful in facilitating learning such as the element of providing good platform of scenario-based learning, memory span, and also pattern recognition. For that reason, chess can be considered as appropriate tool to be used in this study when comparing with other type of games. This argument has been proven in Ferguson's study of chess and critical thinking when he used another games such as Dragon and Dungeons, besides chess.

Results of this study is important in demonstrating the potential of chess in enhancing students' critical thinking skill in Malaysian scenario, which in this country, chess is merely played as hobby rather than as learning enhancement tool in school. This phenomenon is different in the United States, Canada and some European countries where chess has been widely exploited in their school's programme to enhance students' capacity of learning; using chess to improve mathematics, reading, music, history, etc.

Furthermore, more researches are needed when discussing about chess and critical thinking. This study will add new perspectives on how chess has influenced students' learning and whether it is suitable with Malaysian curriculum standards.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

Previous studies have examined chess and its impacts on targeted disciplines or skills using varieties of research designs be it quantitative, qualitative, or mixed methods. Anderson (2004) assessed the correlation between giftedness, gender, age, and chess activity with the level of attention among middle school students. He used d2 Test of Attention to assess students' level of attention after series of chess and other curricular activities took place. The test was administered once during the study since the purpose of test was to compare between two groups of students; the school's chess club and the others after school curricular program. This study was quantitative in nature. Another quantitative study conducted by Saahoon (2005) also exhibited a pre-test and post-test research design. The study examined the cognitive effects of chess instruction on students at risk for academic failure.

Hong (2005) argues that Test of Non-Verbal Intelligence – Third Edition (TONI-3) and Raven's Progressive Matrices (RPM) are distributed to participants of a particular study at the beginning and at the end of the study. The TONI-3 test is administered to measure students' problem solving, aptitude, and reasoning skills. As an improvement to the existing method in similar areas of study, Berkley (2012) used a slightly different approach than Anderson (2004) and Saahoon (2005).

While still relying on quantitative data, Berkley also considered qualitative approach to be applied in his research. This kind of research is called mixed method

research design. Berkley's research was conducted to determine whether the game of chess could be used as an educational tool to improve critical thinking skills, develop students' mathematical skills, and therefore improve their achievement in Mathematics subject at school (Berkley, 2012). In the quantitative phase, a quasi-experimental pre-test and post-test control group design was administered. This study used mathematics test covering mathematical contents that the participants learned and the Watson-Glaser Critical Thinking Appraisal (WGCTA) test. Meanwhile, the qualitative phase applied a narrative design. This design was used to better understand the meaning of experiences among different individuals. In short, those studies clearly demonstrate that research design of a study is dependent on the nature of study; what are the research questions that researcher wishes to answer.

On the other hand, the instrument being selected for assessment also heavily depends on the research objectives. Therefore, it is important for researcher to have clear and feasible objectives before they begin with their fieldworks. A thorough preview of chess literature needs to be done in order to decide which cognitive test would be mostly suitable in answering the research questions. In this chapter, the method used to answer research questions, the selection of samples, the chosen instruments, and the procedure of data collection would be thoroughly explained. This study aims to explore critical thinking and problem solving skills involved during chess intervention on primary school children. Specifically, this study is evaluating the use of chess as a tool to develop students' critical thinking and problem solving skills as measured by the California Critical Thinking Skills Test (CCTST).

3.2 Method of assessment

Previous researches on the development of critical thinking skills among students were built upon various methods for example using either quantitative, qualitative, or mixed method. These could be due to several reasons and one of them is because both quantitative and qualitative methods answer different research question. For example, a quantitative method answers questions on determining what are the elements involved during a study while a qualitative method answers questions on why those elements are chosen or why certain phenomena exists while the research is being conducted. That is why some researchers make use both research methods in order to investigate the 'what' and 'why' aspects. Hence, the mixed method research design seems to be mostly popular in many recent researches in this area. This current study adopted quantitative approach design to investigate the cognitive effects of chess instruction for example the improvement of critical thinking skill on participants as measured by CCTST and school's Science and Mathematics tests. Quantitative type of research is sufficient for this study (Gobet & Campitelli, 2005) to investigate the mean differences between both experiment and control group, also to analyze the relation between critical thinking and science, and critical thinking and mathematics.

The participants consisted of 34 grade four students from two elementary schools located at suburban districts in the Klang Valley of Malaysia. The study used convenient sampling for the selection of participants as it would take half of their school's academic year, thus no compulsion was employed and participants were permitted to withdraw from the study at any time they wanted to. In this quasi-experimental study, a test-retest approach had been administered at the beginning and at the end of study to assess the development of participants' academic performances. The

purpose was to observe whether the intervention program administered on participants did show a positive growth on their cognitive skills. The same test was administered on both experimental and control groups.

Next, the independent variable in this study was chess instruction while the dependent variable was students' performances in the California Critical Thinking Skills Test (CCTST) and also school's Science and Mathematics scores as measured by the difference between pre-test and post-test scores. In achieving the objectives of this study, the pre-test and post-test approaches would help researcher to analyze the impact of one variable over another. In this study, researcher assigned participants to experimental group and control group, administered a pre-test to both groups, conducted intervention activities onto the experimental group only, and then administers a post-test to both groups in order to assess the differences of academic results between both groups (Creswell, 2008).

In this case, Pearson (2008) argued in his research that a test-retest approach is an important part of any research design that investigates the outcomes of playing chess. Unlike true experiment design that contains equal number of experimental and control subjects through random assignment, this type of research design has a different set of participants not through random assignment, but through convenient sampling. This is because in order to perform a longitudinal study and an interventional study, it depends on the availability of participants to participate in the study. In this respective study, by selecting one class as an experimental group and the other class as the control group, this would not disrupt participants' normal learning hours and schedules for chess instruction was not difficult to be followed.

During the intervention program, both control and experimental groups received similar attention during their daily learning sessions in the classrooms. They even had the same set of teachers conducting the class except that the experimental group received chess instruction from chess instructor while the control group did not receive any extra treatment. It was only normal classroom learning. Therefore, any significant improvement in cognitive abilities could be declared as a result of chess-specific activity rather than an effect of merely receiving attention from the teachers.

Figure 3.1 displayed earlier explains the whole process of assessment in this study. The rationale of this study is to determine if learning to play or playing chess has significant impacts on the performance of critical thinking skill among grade five students.

After considering various methods of assessment from previous studies, the one in Figure 3.1 has been used to demonstrate significant results in this study. Each school consisted of two classes of grade four students. One class was assigned as the experimental group (chess group) and the other as the control group (non-chess group). This type of distribution is done because chess instruction will be conducted within school hours which mean students must remain in their respective class for the chess lesson. The control group would not have to learn playing chess during the time interval between the initial and final CCTST evaluations. They also did not make any contact with researcher within that period except during the administration of pre-test and post-test sessions. Assigning a control group in the experiment would provide a clearer picture about the results or outcomes of the study later on (Jones, 2006).

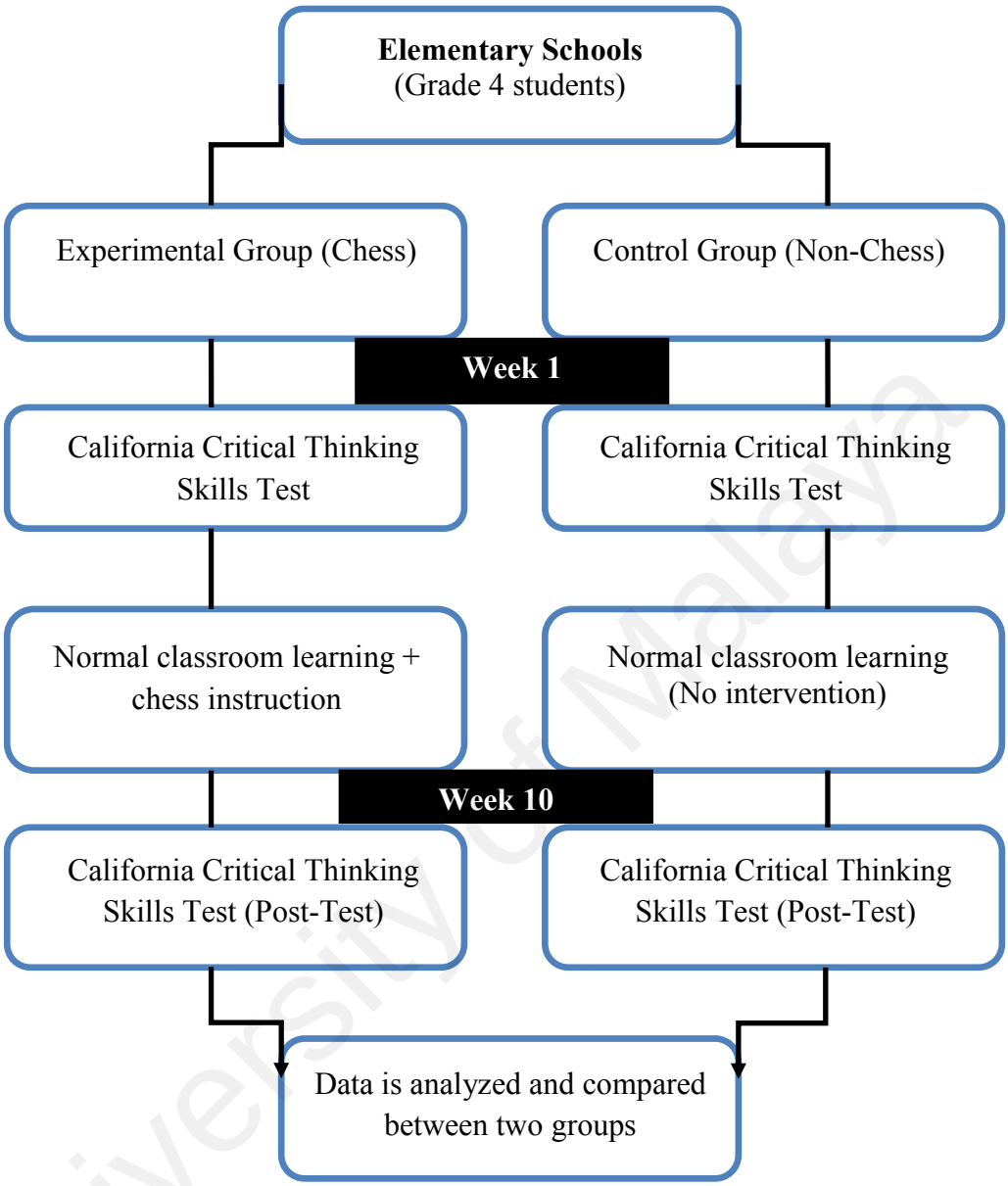

Figure 3.1: Method of assessment.

Both control and experiment groups are subjected to pre-test during the first week of experiment and post-test on the tenth week of experiment. Data is gathered and analyzed using t-test and Pearson's correlation.

Over the years, chess has been proven as an effective learning tool or instruction to develop good thinking skills. Referring to the research design diagram, the method used for this quantitative study is by test-retesting approach. Students were tested using the California Critical Thinking Skills Test (CCTST) to determine the initial performance on their critical thinking skills. After a period determined by researcher which was for the experimental group to learn playing chess, the students were tested again using the same version of the test to determine if the experimental group managed to improve their scores relatively better than the control group. Two schools were selected at the beginning of this study which was during the research proposal process by looking at certain criteria set by researcher. This would be explained further in the sample selection process.

The critical thinking assessment used for this study is designed for elementary school children age 9 to 12 years old, also known as CCTST Form M20. It is developed by The California Academic Press, consisted of 20 questions about solving problems in daily life. Skills are associated with each question tested based on the descriptions of skills suggested by Facione P. A. et al. (2011):

Table 3.1: Cognitive skills tested in the critical thinking test.

Critical thinking skill	Sub-skills	Question number in CCTST
Induction	Drawing warranted probabilistic inferences, drawing probabilistic conclusions.	2, 7, 20
Deduction	Assumed truth of a set of beliefs or premises to a conclusion which follows of necessity.	4, 6, 12, 18

Table 3.1, continued:

Critical thinking skill	Sub-skill	Question number in CCTST
Analysis & Interpretation	Examining ideas, detecting arguments, analyzing arguments, categorization, decoding significance, clarifying meaning.	3, 8, 13,14, 17, 19
Inference	Querying evidence, conjecturing alternatives, drawing conclusions.	1, 9, 10, 16
Evaluation & Explanation	Assessing claims, stating results, justifying procedures, presenting arguments.	5, 11, 15

Participants are assessed based on each question answered. Total scores for the test will be used to analyze findings of the study. The difference of the scores between experiment group and control group is analyzed.

3.3 Translation process of the California Critical Thinking Skills Test (CCTST)

It is acknowledged that official language used by the test takers in this study is Bahasa Malaysia, rigorous translation works have been done to produce the translated version of CCTST M20. The translation project was an online collaboration carried out through electronic mail between the developer, Peter A. Facione and the researcher of this study. A memo of understanding between The California Academic Press and translator reached its agreement. There were several conditions that needed to be met in order to produce the Bahasa Malaysia version of the test. Among others were, researcher should not share the translation materials outside of the translating team; authorization must be given by The California Academic Press before using the translated instrument; the translated instrument could not be published in any form, et cetera.

On the other hand, the translation process in this study used back translation. It began with a team of translator developed the Bahasa Malaysia version of the test. Then, the second team which was another different group of translators that had never seen the original version of the test or involved with the translation process translated the Bahasa Malaysia version back to English version. After that, the new English version was sent back to the developer team for approval. It was Insight Assessment, a division of the California Academic Press.

3.4 Sample of study

Participants for this study consisted of grade four students from two public elementary schools in the Klang Valley which were in the areas of Petaling Jaya and Gombak. These are suburban areas in state of Selangor. They were unequally divided into a control group and experimental group, depending on the number of students in each of the classes at the two participating schools. However, the number of participants decreased during test administration due to their attendance to school during examination day. As Creswell (2008) contended, when selecting participants for a study, some studies might have limited number of participants who are convenient and willing to participate. This also depends on many other factors such as access, funding, overall size of the population, and the number of variables involved.

As presented in the Table 3.1, the participants are made of 41 students from one school, and 35 students from the other school. The sample size is consistent with Pearson's study where there were 53 grade five subjects from two selected elementary schools in northern Ontorio and divided into a control group of 22 students and an experiment group of 31 students (Pearson, 2008).

Table 3.2: Number of participants in the study.

	School A		School B	
	Experimental	**Control**	**Experimental**	**Control**
Boys	9	13	8	13
Girls	9	10	8	6
	18	23	16	19
Total	41		35	

Barrett (2010) was also having limited number of participants in his study exploring the role of chess in improving mathematical skills. This is because the nature of such study permits only students who are available and willing to participate from the beginning until the end period of study which normally takes about ten to fifteen weeks to finish. A total of 31 participants in which 16 for the control group and 15 for the experimental group were selected for Barret's study (Barret, 2010).

In addition to that, Gall et al. (2006) also argued that for a causal-comparative and experimental research, there should be at least 15 participants in each group to be compared. Grade four students were selected for this study due to the concern raised by the Ministry of Education which not to use subjects from the examination classes for instance grade six since they would be taking their end-of-the-year elementary school examination, also known as *Ujian Penilaian Sekolah Rendah* soon. For this matter, researcher avoided the grade five classes too since they had already started their preparation class for the examination in the following year.

3.4.1 Selection of sample of study

Both schools were located within close geographic proximity of each other. They were similar in terms of curriculum program and no chess club had ever been established in these two schools. This factor is important to ensure that control groups received no formal chess instruction or such from any institution or club so that the impacts of chess instructions in this study could be taken into account more reliably. Like any other convenient samples, both schools were willing to cooperate with researcher in terms of incorporating chess instruction into their curriculum program. This process had been applied to the experimental groups only while the control groups followed the conventional classroom lessons without chess instruction.

In quasi-experimental study like this, participants are selected based on their level of schooling; grade four students. This selection is based on the requirement given by the Ministry of Education; participants of a study must not include students from *Ujian Penilaian Sekolah* Rendah that is grade six students. From the whole grade four sample, researcher has randomly assigned one class as experiment group, and the other class as control group. Both classes was instructed by the same set of teachers for their conventional school subjects, therefore one of internal validity threat has been avoided in this study.

Figure 3.2: Participants consisted of grade four students (Research photograph).

Researcher has also ensured that participants from both group have never received any formal lesson on chess, nor know how to play the game. Therefore, the effectiveness of this study is not affected by external factor; both groups have the same level of chess lesson. Screen test has been conducted prior to this study to ensure participants have never played chess.

Experiment groups followed chess instruction during one period of their school subjects either during arts class or moral lesson. The selection of period was done based on school principal's decision by avoiding taking the lessons of critical subjects like Science, Mathematics, Bahasa Malaysia, and English Language to teach participants how to play chess. Chess lesson could not be conducted outside schooling hours due to limitation of funding and the availability of participants. Meanwhile, control group of

this study following conventional school lessons as usual, and not exposed to this study or any chess lessons inside and outside school. Participants from both groups are subjected to pre-test and post-test on critical thinking skill test, mathematic subject test, and also science subject test.

3.5 Materials

For chess instructor, there were seventeen sets of chessboards and one set of wall chessboard used in this study. Each pair of subjects in the experimental group was given one set of chessboard to be used during the intervention. They were required to write their names on each set to prevent missing of chessboard in the future. In that way, they were asked to be responsible for their own chess set during the entire period of study.

A Chess Teaching Manual based on training and materials from Malaysian Chess Federation had been produced for this study. It consists of four levels of chess learning which are chess basics, chess openings, chess tactics, and chess strategies. See Appendix A for teaching manual designed for this study. For the purpose of this study, researcher's team, assistants, and chess instructor were responsible for the development of the teaching material. They were allowed to adjust approaches suggested in the manual to suit the students' additional needs. As for the testing package, an authorized translated version of the California Critical Thinking Skills Test (Form M) was published by Insight Assessment, a division of the California Academic Press. A set of 76 question papers as attached in Appendix B and answer sheets were purchased to be administered during the pre-test and post-test sessions. A test manual is attached in Appendix C was also included together with the packages purchased.

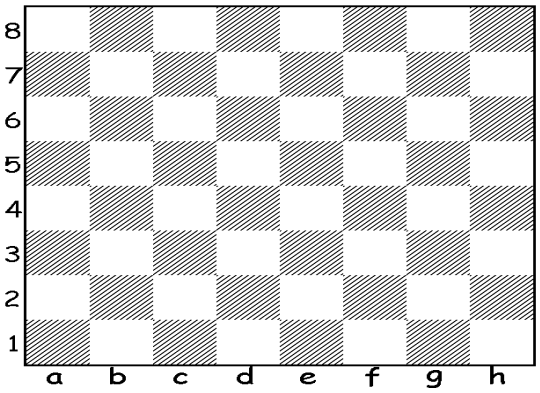

Figure 3.3: The chess board

Figure 3.4: Chess pieces

3.6 Procedures

This quasi-experimental study went through phases of getting informed consent, teaching and assessment planning, and experiment intervention in order to accomplish its objectives, including obtaining consents from participated authorities, assigning research subjects to experimental and control groups, and finally conducting designed interventions.

3.6.1 Informed consents and parental awareness

Obtaining informed consent from research subjects is a critical part in any clinical or educational research. This is because participants have the right to be fully informed of any risk and benefit. As suggested by Cowell (2011), few basic components

of informed consent must include (1) full disclosure of the nature and purpose of the nature; (2) adequate information about the participations and expectations of research; (3) voluntary choice to participate in the study. For this study, informed consent from three parties must be obtained before the research started including the Malaysia's Ministry of Education (MOE), the school authorities, and the parents of the participants. Each party must be aware about the risks and benefits of this study to each respective organization or the children themselves. A separate type of consent form had been submitted for this purpose.

There was also a specific kind of form produced by the MOE for the researcher called the *Borang Bahagian Perancangan dan Penyelidikan Pendidikan* (BPPDP1). Researcher had to submit this form together with research proposal, presenting the details of research program at the schools involved. Subsequently, an authorization letter had been given to mark the approval of the research. As for the participating schools, series of visits and discussions with every teacher-in-charge of this program, who was normally the Vice Principal of Students' Affairs, had taken place before the research even started. Visits to schools had been organized to observe research environment, particularly in identifying the research subjects and suitable locations around the schools to conduct the chess lessons.

Prior to all the steps mentioned before, a letter applying for permission from the school authority had been submitted at the beginning of school year in 2010. The letter consisted details about the research such as method involved as well as associated risks and benefits that each school would gain from the program (Appendix E). The program brochure is also attached for reference. Likewise, a consent letter had also been given to parents and guardians informing that their children would be involved in the study as

subjects. The letter also consisted details about the research such as method involved as well as associated risks and benefits that each school would gain from the program. Program brochure and consent form were attached together with the letter. The form was a written consent for parents and guardians to permit their children to participate in the study. It was written in the form that participants were permitted to withdraw from the study whenever they wanted to as shown in Appendix E.

3.6.2 Teaching planning

Series of visits and discussions had taken place with the school authority to arrange the schedules of the chess lessons in which researcher planned to conduct a chess lesson approximately within one hour to two hours per week. For that matter, researcher had been given one class period to conduct the class. For school A, chess class was conducted at the computer lab, while school B used the library instead. The content of the chess lesson was designed based on Malaysian Chess Federation module and a guideline given by Keith Storey, an associate professor in the field of education, specializing in the investigation of appropriate method to teach chess at school (Storey, 2000). It basically covered four stages of scholastic chess comprising of basics of chess, chess openings, chess tactics, and the end game (Appendix A). The suitable dates for pre-test and post-test of critical thinking tests had also been proposed during the visits and discussions.

3.6.3 Assignment of participants

Participants were assigned to experimental group and control group before the study started. There were two classes of grade four in each school. The entire class sections were selected as experimental group and control group respectively, except for school A which has a bigger number of students in each class. Therefore, for school A,

only 18 students were available and willing to participate in the study. The number of students conformed to Gall's suggestion on the number of participants for experimental study. He argued that at least 15 participants are needed in any quantitative study (Gall et al., 2006). Students in the experimental group received chess lessons during normal schooling hours in the classroom. The learning hours differed from one school to another, depending on the learning hours provided by the school, such as 90 minutes to 120 minutes. At the same time, students in the control group were not exposed to any chess lesson during the entire study.

3.6.4 Pre-test and post-test procedures

The translated version of Bahasa Malaysia of the California Critical Thinking Skills Test – M Series was developed by researcher and the developer of the test, Dr. Peter A. Facione from Insight Assessment, a division of the California Academic Press using back-translation process. It is a critical thinking test developed for students in grade three to grade five. The original version was in English. Since Bahasa Malaysia is the first language of Malaysia's school curriculum, it was appropriate to use the translated version in this study. The assessment script consisted of 20 multiple choice questions which examined students' cognitive abilities to analyze, evaluate, and make deduction out of the situations given in the questions. It was basically a scenario-based type of questions. Students were required to break problems into small parts and solve them systematically. See Appendix B for sample questions.

Both experimental and controlled participants were administered at the same time to avoid leaked questions among the students. A unique ID number was created for each participant for the purpose of score reports for each test taker. No two answer

sheets should have the same ID number. Test takers need to write down their unique ID number and darken the correct bubbles on the CapScore answer sheet. The CapScore paper-and-pencil testing instructions were read to the participants. Test takers were given 45 minutes to complete the test. Pre-test was conducted to note any difference in the scores that participants might get prior to the beginning of the unit of study.

The unit of study took ten weeks to be completed. During the unit of study, all participants received the same content of classroom learning, under the same condition, and by the same set of teachers. Except for the experimental group, they received extra class on chess playing that would gradually develop their abilities to solve problems. On the last day of the study, a post-test had been administered to all participants using the same instrument used for pre-test, but using a new set of question papers. This was purposely done to note down any difference between the participants' pre-test and post-test scores. Results of the study were analyzed using a t-test.

3.6.5 The experiment – chess instructions

The experimental group received ten weeks of chess instructions while the control group did not. The chess lesson was designed by researcher together with research assistant, based on the training given by the Malaysian Chess Federation. The module consisted of four levels of chess learning which are chess basics, chess openings, chess tactics, and chess strategies (Appendix A). The ten week of lessons conducted by researcher was consistent with Pearson's study in 2008. Pearson explored the effects of learning to play chess on non-verbal reasoning abilities. He conducted only nine weeks of chess instruction consisted of 26 lessons outlined in the Chess

Training Manual published by the Chess Federation of Canada (Pearson, 2008). Each lesson lasted for approximately half an hour and this study had been successfully completed in the period of three months.

In addition, the class was conducted by at least one designated, professionally-trained instructor without any intervention from the facilitator or researcher. In the first week, the lessons started with a brief history of chess and the introduction to all chess pieces, as well as all tactical and strategies of the game towards the end of the lessons.

Figure 3.5: There were at least one instructor, one facilitator, and the researcher as the participants' observers involved in each chess lesson (Research photograph)

Besides that, both schools did not have their own chess club, and they had given full cooperation not to teach chess or set up chess club at their schools during the intervention. However, it was impossible for researcher to ensure that no participants

got themselves engaged in any chess lesson outside of the school within the period of three months of this study.

At the beginning of the study, an informal survey discovered that no participants had ever received formal chess lessons. Most of them played the game occasionally with their relatives and friends, but did not really know and understand its rules and strategies. Some of them even got the wrong information on the move of the chess pieces. That was the main reason why the chess lessons had been designed starting from the very basic knowledge about chess until the tactics and strategies of the game (Appendix A**).**

Figure 3.6: Students demonstrated their chess moves on the instructor's chessboard (Research photograph)

Figure 3.7: Students did not only enjoy playing chess, but also enjoyed doing exercises from handouts (Research photograph).

Experiment group were encouraged to play the game during recess time or after school to practice all the skills that they learned during the chess lessons. By doing this, participants would be able to detect any mistake that they might commit and asked their instructors later in the class. This would also act as a revision for the entire class.

3.6.6 Pilot study

A pilot study has been conducted in two schools located in petaling jaya in 2010, to test the critical thinking assessment paper. They were *Sekolah Kebangsaan (2) Sultan Alam Shah* and *Sekolah Kebangsaan Sri Damai*. While conducting the test, researcher gathered information on improvement needed for the assessment. This phase of research is important in making sure the assessment was translated properly and that participants can easily understand the questions asked in the assessment paper.

3.7 Data analysis

The current study aims to investigate the impact of chess on students' ability to think critically and solve problems. Using test-retest approach by conducting pre-test and post-test sessions, the independent variable for this study was the intervention of chess playing, while the dependent variable was participants' scores on the California Critical Thinking Skills Test (CCTST), as well as school's Science and Mathematics scores. In this case, it is possible that the independent variable effects the dependent variable. All answer sheets of the CCTST were returned to the test developer, Insight Assessment, every time after the test administration for scoring purpose. The results had been received by researcher about one month afterwards. Two documents on raw data were received by researcher, which were individual scores for pre-test and post-test, as well as group statistics for pre-test and post-test.

For individual score (Appendix F), the data was segregated by identification number, group, gender, ethnicity, and the elements of critical thinking skills tested including induction, deduction, analysis and interpretation, inference, evaluation, and explanation. Descriptive statistics for group scores were also included; the mean, median, standard deviation, and standard error of the mean. The difference of the mean scores for each group was measured and a paired *t*-test had been conducted to determine significant difference between both groups. Besides that, categorical cut scores recommended by the developer were used to explain different scores in each group. The following is the cut scores recommended:

Table 3.3: Categorical cut scores

Scores	Interpretation
60 – 72	Not manifested
73 – 78	Emerging
79 – 84	Strong
85 or higher	Superior

This standard was used to interpret the overall performance of each group in the study. All five skills concerned with critical thinking were also interpreted in the same manner using the recommended standard scale of scores.

CHAPTER 4: RESULTS

4.1 Overview

Inculcating the habits of thinking into children's mind is an important task to be carried out by parents and schools. School should always promote good thinking skills through various fun-learning programs to attract students' interest on the activities. Critical thinking should not be viewed as a formal course to be learned at school, rather it could be learned through daily activities such as chess playing. The game of chess should be part of the regular school's curriculum. This is important to ensure that all students would be able to participate in the activity as well as to connect other critical thinking learning activities with other subjects offered by the school. Gerner (2011) suggested that academic achievement could be improved when critical thinking learning activities are infused within classroom learning setting.

This way, the relevant transferable skills acquired during critical thinking activities could be applied by students in learning other subjects. The literature suggests that one who plays chess is required to think critically. The ability to think critically should improve students' performances in mathematics and science subjects, particularly in the aspect of problem solving. Thus, it is expected that the skills learned from the game chess are transferred to improve critical thinking and problem solving skills. In the context of this study, participants were observed throughout the chess lesson. All lessons had been recorded should there be any overlooked data. In this case, researcher would be able to improve instruction approach when necessary.

This study had also been designed to investigate the potential relationship between chess instructional strategies with mathematics and science curriculum at

school. Participants' performances were assessed using the California Critical Thinking Skills Test (CCTS) and school's end-of-the-year grades. Participants in this study consisted of fifth grade students from two elementary schools in two suburban districts located in the middle west of Peninsular Malaysia. For each school, participants in the experiment group had to attend chess lessons once a week for 10 weeks, while participants in the control group did not attend any chess lessons. They only had the standard lessons for both mathematics and science.

In this design, pre-test and post-test were administered to each participant to observe significant changes between experiment and control groups' performances. Table 4.1 shows the distribution of participants for this study. The distribution of participants for this study used convenient sampling based on the consents given by their parents. No compulsion was employed and subjects were permitted to withdraw from the study at any time they wanted to. The research design used in this study selected participants not through random assignment, unlike true experiment design that has equal number of experimental and control subjects. No artificial groups were created for this experiment. By selecting one class as experimental group and the other class as control group would not disrupt participants' normal classroom learning session. Also, the schedule for chess instruction was not difficult to be followed.

Table 4.1: Distribution of participants in each participated school.

	school A		**school B**	
	Experimental	Control	Experimental	Control
Boys	9	13	8	13
Girls	9	10	8	6

Table 4.1, continued:

	school A		**school B**	
	Experimental	Control	Experimental	Control
	18	23	16	19
Total	41		35	

4.2 Data analysis

A quasi-experimental pre-test and post-test design with non-equivalent groups was used for this study. The dependent variable used was the scores of California Critical Thinking Skills Test (CCTST), as well as end-of-the-year science and mathematics subjects' school examination.

Main objective of this study is to see whether playing chess will significantly improve students' critical thinking skill. This can be done by looking at the results of the critical thinking assessment (CCTST). Mean difference between both experiment and control groups will be compared.

Next, researcher will observe whether playing chess will improve students' mathematics and science scores or not. These two subjects are chosen because there are elements of critical thinking and problem solving skills in the content of this subjects. Moreover, it is argued that Malaysian students are below international average level in conducting problem solving activity based on PISA and TIMSS results.

Lastly, it will be very significant to observe the relation between critical thinking and mathematics, also between critical thinking and science. For this part, Pearson's test will be used to relate those variables.

There were two schools participated in this study for the purpose of getting significance results through appropriate sample size. The result of this study, thus, would be presented according to hypothesis tested in each school. It started with school A and followed by school B.

4.2.1 Chess and critical thinking skills

The first hypothesis predicted that there would be a significant difference between pre-test scores and post-test scores of the California Critical Thinking Skills Test within the experiment group. The California Critical Thinking Skill Test (CCTST) had been administered to participants prior to chess intervention and at the end of the program. Adjusted mean scores for the CCTST within group were derived to determine the results' differences between pre-test and post-test for each group.

a) Critical thinking assessment for school A

Figure 4.1 shows the mean scores of the California Critical Thinking Skills Test (CCTST) for school A. Experiment group's post-test score shows 0.6 points higher than their pre-test score, while control group's post-test score declines 1.4 points than their pre-test score. From the result, we could see that both groups demonstrate a difference in their pre-test scores and post-test scores.

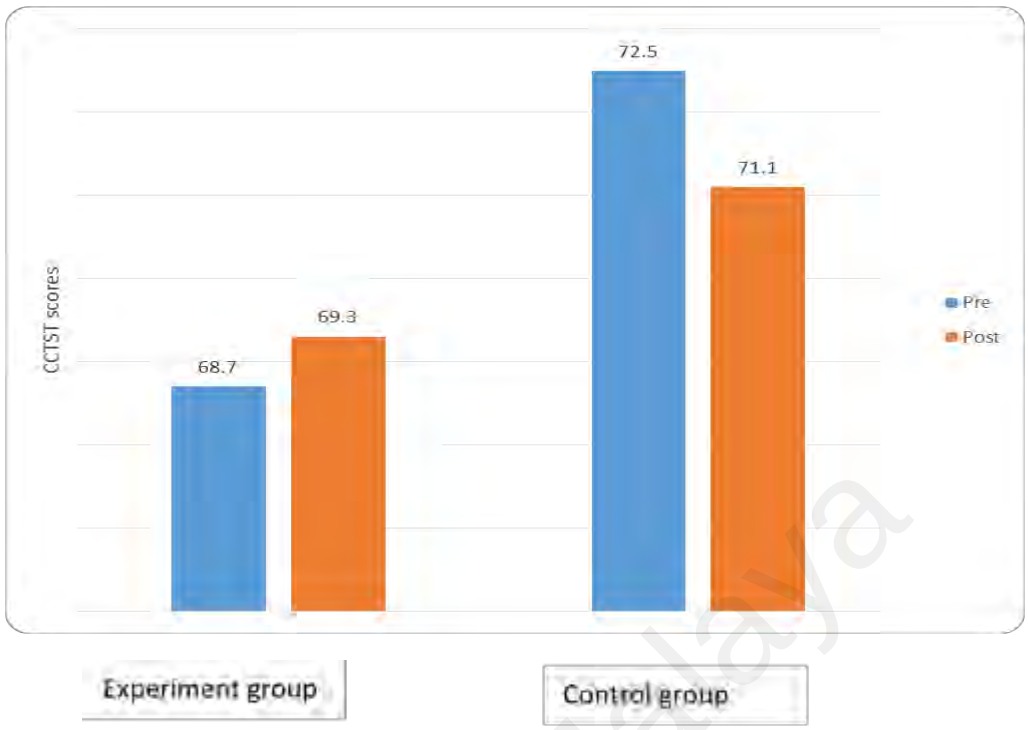

Figure 4.1: The mean scores of the California Critical Thinking Skills Test (CCTST) for experiment and control groups for school A

Table 4.2: Pre-test and post-test of experiment group for school A

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	68.73	2.81	0.68
Post-Test	69.31	2.89	0.77
	T-value = -0.69 (T-Critical = 2.16)	P-value = 0.51 (α = 0.05)	Degree of Freedom = 13

As shown in Table 4.2, we could see that the mean of the post-test score is 0.58 higher than pre-test score within experiment group of school A. This indicates an increase in the scores by experiment group. However, from the *t*-test result, it shows that T-value < T-critical (0.69 < 2.16) and P-value > α (0.51 > 0.05). This indicates that there is no significant difference between the participants' pre-test and post-test scores. Therefore, the hypothesis is rejected.

Table 4.3: Pre-test and post-test of control group for school A

	Mean	Standard Deviation	Standard Error of the Mean
Pre-Test	72.55	4.25	1.28
Post-Test	71.11	3.61	1.04
	T-value = 1.29 (T-critical = 2.23)	P-value = 0.23 (α = 0.05)	Degree of Freedom = 10

A *t*-test with unequal variances was conducted on the pre-test and post-test mean scores for the control group to determine if there is any significant difference within the group. Results of the paired test in Table 4.3 shows that T-value < T-critical (1.29 < 2.23) and P-value > α (0.23 > 0.05). For that reason, it indicates that there is no significant difference within the control group of school A neither. Table 4.2 and 4.3 demonstrate that there are no significant differences between pre-test and post-test scores of the CCTST within each group in school A. Although both groups do not show significant increase from pre-test to post-test, the mean score of control group is still higher than the mean score of experiment group.

b) Critical thinking assessment for school B

There is a similar pattern appears in school B. Experiment group's post-test score increases by 3.0 points than their pre-test score. Meanwhile, control group's post-test score declines by 1.0 point than their pre-test score. Similar *t*-test had been applied to school B to see if there is any significant difference within each group, both for experiment group and control group.

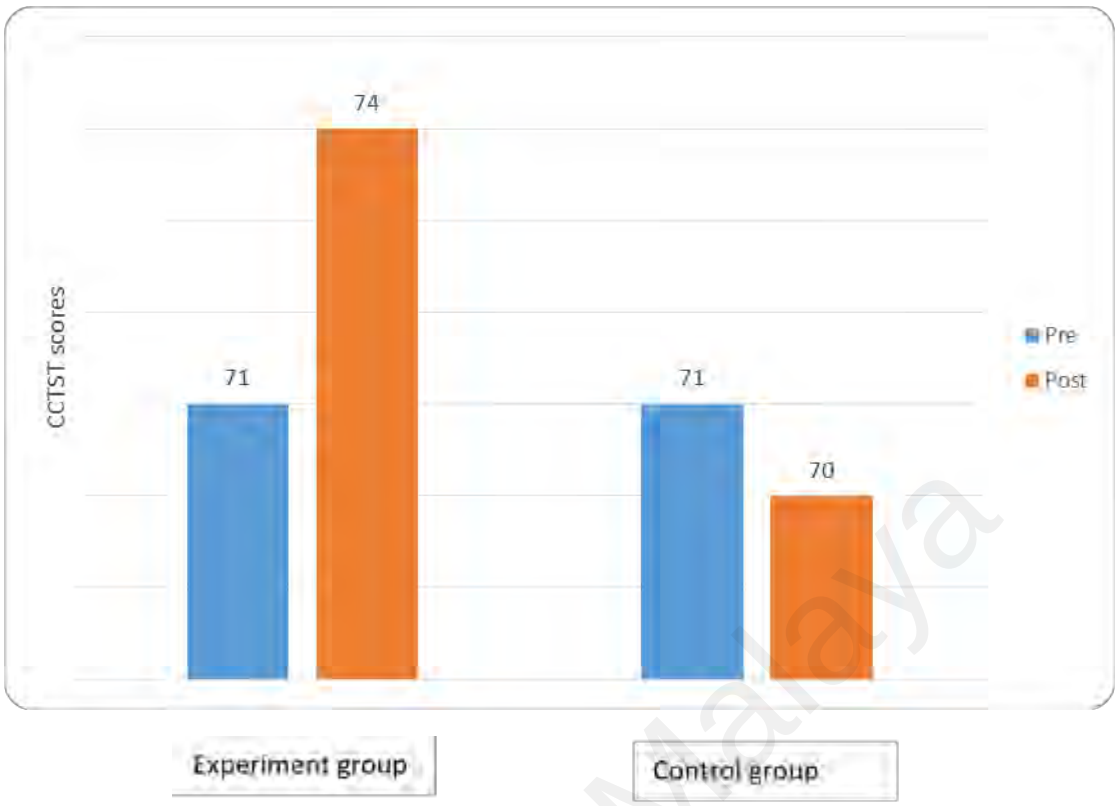

Figure 4.2: The mean scores of the California Critical Thinking Skills Test (CCTST) for experiment and control groups for school B

Table 4.4: Pre-test and post-test of critical thinking assessment for experiment group for school B

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	71.14	4.03	0.84
Post-Test	73.96	3.08	0.77
	T-value = 2.59 (T-critical =2.13)	P-value = 0.02 ($\alpha = 0.05$)	Degree of Freedom = 15

As what could be seen in Table 4.4, the results of the *t*-test show a significant difference between the pre-test and the post-test scores of the CCTST for the experiment group in school B. The T-value is higher than the T-critical (2.59 > 2.13), while the *p*-value is 0.02 which is less than the alpha of 0.05. This indicates a significant difference in the subjects' critical thinking skills.

Table 4.5: Pre-test and post-test of control group of critical thinking assessment for school B

	Mean	Standard Deviation	Standard Error of the Mean
Pre-Test	71.55	4.61	1.06
Post-Test	70.42	4.70	1.42
	T-value = 0.49 (T-critical = 2.23)	P-value = 0.63 (α = 0.05)	Degree of Freedom = 10

The same test had also been applied to control group of the same school to see if there is any significant difference between the pre-test and post-test scores within the group. The mean score of the post-test declines by 1.13 points from the pre-test. The T-value is lesser than T-critical ($0.49 < 2.23$), while P-value is higher than α ($0.63 > 0.05$). Therefore, the results show no significant difference between the pre-test and post-test scores of the control group in school B.

4.2.2 Chess and mathematics

The second hypothesis is related to the significant difference between pre-test and post-test scores of mathematics subject in the experiment group. The mathematics scores produced by participants in the middle of 2011 serve as pre-test measure while Mathematics scores in the end-of-the-year test is the post-test measure.

a) Mathematics scores for school A

The mean of pre-test scores for the two groups, experiment and control, are as followed; the control group's mean score is 67.52 (SD = 20.05) and the experiment group's mean score is 48.56 (SD = 15.82). In 2011, the mean for post-test was 65.52 (SD = 16.26) for the control group and 50.44 (SD = 15.85) for the experiment group. Figure 4.3 shows the participants' mean score for mathematics from school A. The

experiment group's post-test score is 1.88 points higher than their pre-test score, while the control group's post-test score declines by 2.0 points than their pre-test score. From the results, there are significant differences in both groups' pre-test and post-test scores.

A pair of two samples for *t*-test with unequal variances has been conducted to determine any significant difference that might appear within each group. The test used the value of mean to derive each group's standard deviation and to observe dispersion between experiment value and expected value. P-value and T-value are calculated to test out the hypothesis stated for this part of question.

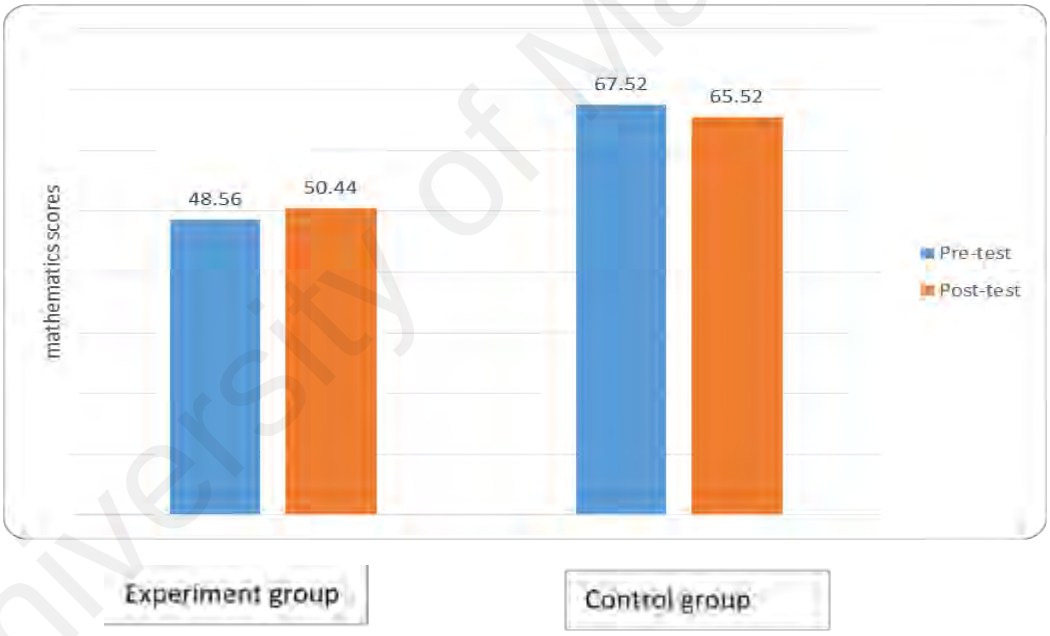

Figure 4.3: The mean scores of mathematics assessment for experiment and control groups from school A

Table 4.6: Pre-test and post-test of mathematics assessment for experiment group for school A

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	48.56	15.82	3.73
Post-Test	50.44	15.85	3.74
	T-value = 1.14 (T-critical =2.11)	P-value = 0.27 ($\alpha = 0.05$)	Degree of Freedom = 17

The results of *t*-test indicate that there is no significant difference between pre-test and post-test scores in mathematics for experiment group in school A. As shown in Table 4.6, the T-value is lower than the T-critical (1.14 < 2.11) and the P-value is 0.27, which is higher than the alpha of 0.05. This implies that the increment of mathematics scores by experiment group during post-test shows no significant difference.

Table 4.7: Pre-test and post-test of mathematics assessment for control group for school A

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	67.52	20.05	4.18
Post-Test	65.52	16.26	3.39
	T-value = 1.12 (T-critical = 2.07)	P-value = 0.28 (α = 0.05)	Degree of Freedom = 22

In the Table 4.7, the mean value of post-test scores for the control group declines by 2.0 points lower than the pre-test scores. However, the *t*-test shows no significant difference in the scores as the T-value has lower points than T-critical (1.12 < 2.07), while P-value is higher than alpha value of 0.05 (0.28 > 0.05). Table 4.5 and 4.6 demonstrate that there is no significant difference between pre-test and post-test scores of mathematics assessment within each group in school A. Although both groups do not show significant increases from pre-test to post-test, the mean scores of experiment group is higher than the mean scores of control group.

b) Mathematics scores for school B

Results show that both groups in school B earn higher scores in their post-test. The mean scores of the experiment group is 5.06 points higher in the post-test compared to the pre-test. Meanwhile, the post-test scores for control group is 1.79 points higher than the pre-test scores. Both groups show increment in their mathematics test

performance, but experiment group shows larger difference than the control group. A paired *t*-test was conducted to determine the significant differences.

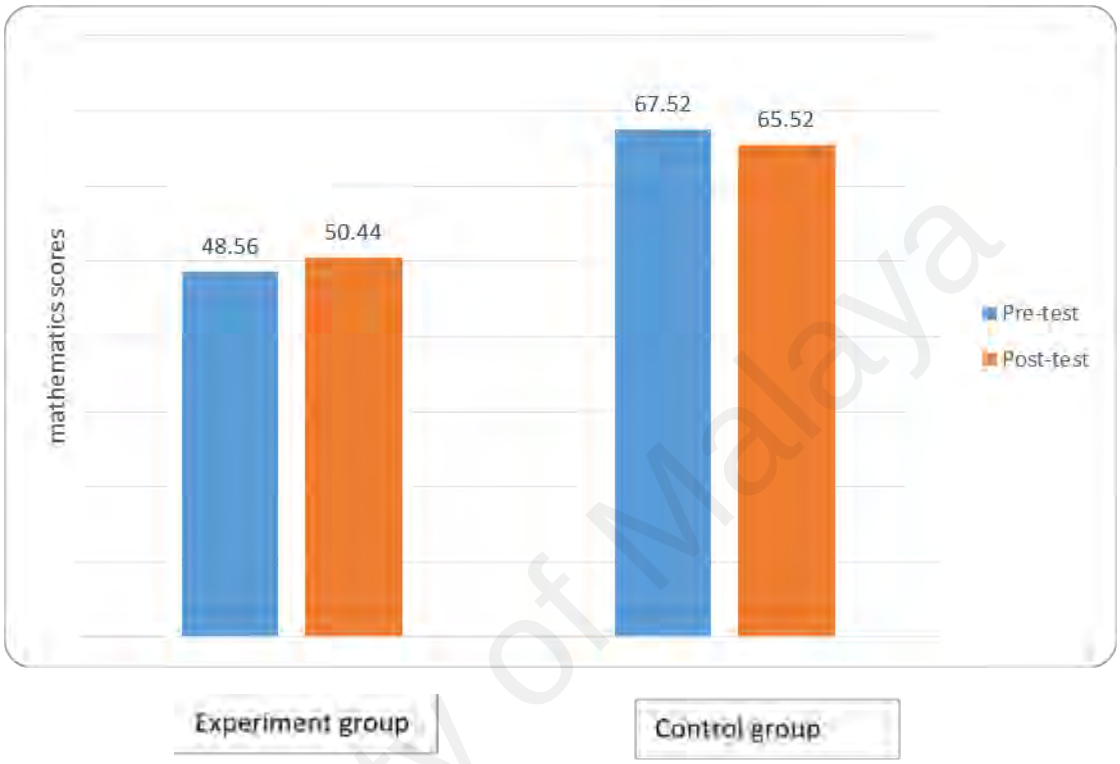

Figure 4.4: The mean of the Mathematics assessment scores for experiment and control groups of school B

From the *t*-test conducted, the T-value is higher than the T-critical (2.62 > 2.13) and the P-value is lower than the alpha (0.02 < 0.05). This indicates significant improvement in participants' Mathematics scores.

Table 4.8: Pre-test and post-test of mathematics assessment scores for experiment group of school B

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	46.63	8.86	2.22
Post-Test	51.69	9.76	2.44
	T-value = 2.62 (T-critical = 2.13)	P-value = 0.02 (α = 0.05)	Degree of Freedom = 15

Table 4.9: Pre-test and post-test of mathematics assessment scores for control group of school B

	Mean	Standard Deviation	Standard Error of the Mean
Pre-Test	46.21	20.17	4.63
Post-Test	48	19.85	4.55
	T-value = 0.84 (T-critical = 2.10)	P-value = 0.41 ($\alpha = 0.05$)	Degree of Freedom = 18

The control group in school B has higher mean score in their mathematics' post-test, 1.79 points difference in the post-test than to pre-test. However, the *t*-test conducted does not show significant improvement in the score. The T-value is lower than the T-critical ($0.84 < 2.10$), and the P-value is higher than alpha ($0.41 > 0.05$). Table 4.8 and Table 4.9 display that the experiment group in school B has significant improvement in participants' mathematics scores in comparison to the control group. This could also be seen from the large difference between the mean scores of post-test and pre-test in the experiment group.

4.2.3 Chess and science

For this question, it is predicted that the chess instruction increases students' performance in science subject. This means that there must be a significant difference between the participants' pre-test scores and post-test scores in the experiment group. The results of the middle semester test in 2011 serves as the pre-test indicator while the end-of-the-year science scores would be used as the post-test indicator.

a) Science scores for school A

Figure 4.5 shows the mean of science scores by participants of school A. Small differences do appear between the results of pre-test and post-test in both groups.

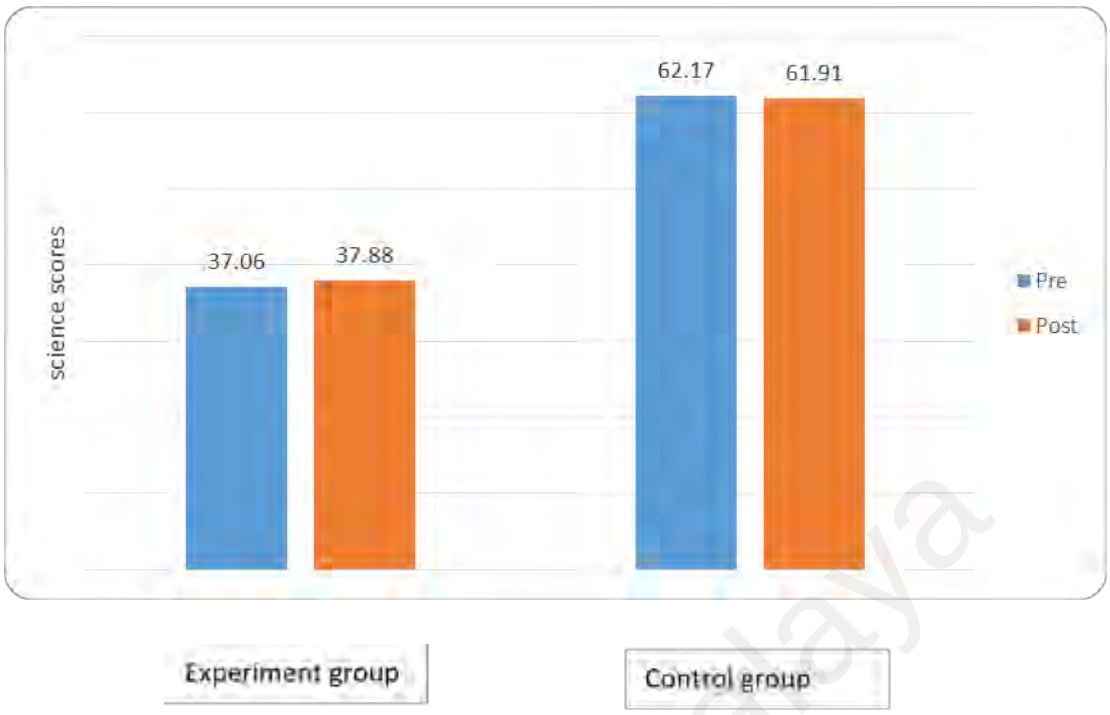

Figure 4.5: The mean of the science scores for experiment and control groups of school A

The experiment group scores 37.06 in pre-test and 36.89 in the post-test, 0.82 points in the difference. Meanwhile, the control group scores 62.17 in pre-test and 61.91 in the post-test, which is 0.26 points lower in the difference. In order for researcher to determine any significant difference in the scores, a paired *t*-test with two samples for mean has been conducted.

Table 4.10: Pre-test and post-test of science assessment scores for experiment group of school A

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	37.06	13.14	3.19
Post-Test	36.89	11.93	2.81
	t-value = 0.42 (*t*-critical = 2.12)	*p*-value = 0.68 (α = 0.05)	Degree of Freedom = 16

The paired *t*-test that was conducted shows no significant difference between pre and post-test within both groups. For experiment group, *t*-value is lower than *t*-critical (0.42 < 2.12) while *p*-value is higher than alpha (0.68 > 0.05).

Similar results in control group, *t*-value is lower than *t*-critical (0.15 < 2.07) and *p*-value is higher than alpha (0.88 > 0.05). Therefore, it is suffice to conclude that chess instruction has no significant effect to participants' performances in science subject based on their school's science test result.

Table 4.11: Pre-test and post-test of science assessment scores for control group of school A

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	62.18	10.62	2.21
Post-Test	61.91	10.51	2.19
	t-value = 0.15 (*t*-critical = 2.07)	*p*-value = 0.88 (α = 0.05)	Degree of Freedom = 22

b) Science scores for school B

From Figure 4.6, both groups in school B demonstrate a decline in their science post-test in contrast with their pre-test. Experiment group loses scores 69.75 in the pre-test and 64.38 in the post-test, which is 5.37 points in the decline. Meanwhile, control group scores 65.89 in their pre-test and 65.49 in the post-test, which shows 0.42 points in the decline. However, its significant difference is yet to be determined using paired *t*-test with two samples for mean.

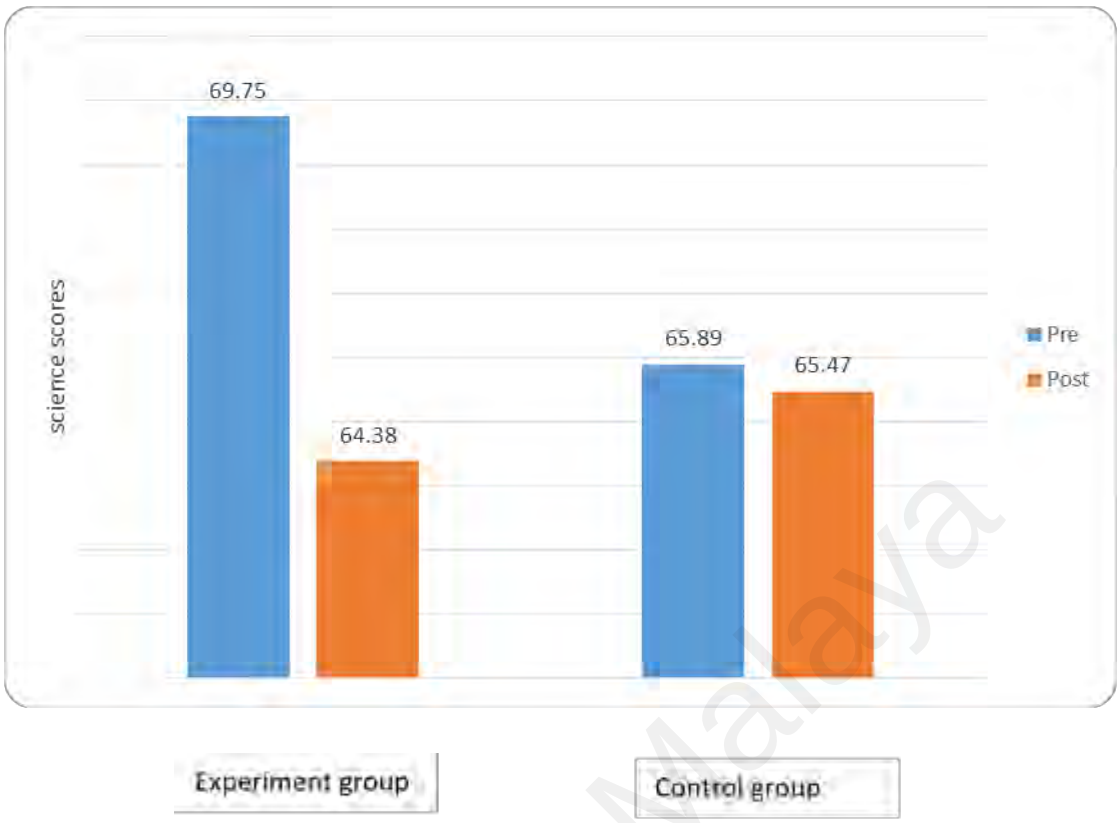

Figure 4.6: The mean of the science assessment scores for experiment and control groups of school B

Table 4.12: Pre-test and post-test of science scores for experiment group of school B

	Mean	**Standard Deviation**	**Standard Error of the Mean**
Pre-Test	69.75	12.56	3.14
Post-Test	64.38	12.99	3.25
	t-value = 2.54 (*t*-critical = 2.13)	*p*-value = 0.02 (α = 0.05)	Degree of Freedom = 15

Table 4.12 shows that the experiment group from school B has a significant difference in their science test performance. The *t*-value of the group is higher than *t*-critical (2.54 > 2.13) and its *p*-value is lower than alpha (0.02 < 0.05).

Table 4.13: Pre-test and post-test of science scores for control group of school B

	Mean	Standard Deviation	Standard Error of the Mean
Pre-Test	65.89	11.93	2.74
Post-Test	65.47	15.84	3.63
	t-value = 0.19 (*t*-critical = 2.10)	*p*-value = 0.85 (α = 0.05)	Degree of Freedom = 18

Next, different results shown for the control group as compared to experiment group. Its *t*-value is lower than *t*-critical (0.19 < 2.10) while *p*-value is higher than alpha (0.85 > 0.05). This indicates that the differences demonstrated in their scores have no significant effect. By referring to the mean scores of science's performance in both schools, it could be concluded that chess instruction has no effects on students' performance in science subject. This is due to the fact that there is no significant difference discovered in their post-test as compared to pre-test in any group in both schools. Nonetheless, it is important to note that students do learn, acquire, and polish their problem solving skills during chess instruction. At the moment, the question on how to apply the skills deems to be more significant for researcher to find out hence more research is needed for this similar type of study.

4.2.4 Critical thinking skills and mathematics

From the results demonstrated earlier, it is important to determine significant correlation between mathematics scores and students' ability to think critically. To answer this question, Pearson's product-moment correlation is being utilized. The following are the results of the test.

a) Critical thinking and mathematics for school A

The following table shows a weak, positive correlation between critical thinking and mathematics achievement ($r = 0.266$, $r = 0.444$, $p < 0.05$):

Table 4.14: Correlation matrix for the Pearson's product-moment correlation for experiment and control group, pre-test CCTST and pre-test mathematics for school A (significant at 0.05 level)

Variables	**Pre-test CCTST**		**Pre-test mathematics**
	Experiment group	Control group	
Pre-test CCTST	1	1	
Pre-test mathematics	0.266	0.444	1

b) Critical thinking and mathematics for school B

From the Pearson's product-moment correlation test conducted, the control group from school B shows greatest correlation between critical thinking skill and mathematics achievement ($r = 0.636$, $p < 0.05$).

On the other hand, for the experiment group of school B, the result shows a weak, negative correlation between critical thinking and mathematics achievement ($r = -0.194$, $p < 0.05$).

Table 4.15: Correlation matrix for the Pearson's product-moment correlation for experiment and control group, pre-test CCTST and pre-test mathematics for school B (significant at 0.05 level)

Variables	**Pre-test CCTST**		**Pre-test mathematics**
	Experiment group	Control group	
Pre-test CCTST	1	1	
Pre-test mathematics	-0.194	0.636	1

4.2.5 Critical thinking skills and science

The hypothesis predicts that there is a correlation between critical thinking skill and participants' science performance. Pearson's product-moment correlation is being utilized to determine the correlation. Students' mean scores in CCTST and school's science test serve as variables.

a) Critical thinking and science for school A

Following table shows that experiment group from school A has greater correlation than their control group:

Table 4.16: Correlation matrix for the Pearson's product-moment correlation for experiment and control group, pre-test CCTST and pre-test science for school A (significant at 0.05 level)

Variables	**Pre-test CCTST**		**Pre-test science**
	Experiment group	Control group	
Pre-test CCTST	1	1	
Pre-test science	0.519	0.168	1

b) Critical thinking and science for school B

School B shows different pattern in the correlation test which control group demonstrates greater correlation between critical thinking and science:

Table 4.17: Correlation matrix for the Pearson's product-moment correlation for experiment and control group, pre-test CCTST and pre-test science for school B (significant at the 0.05 level)

Variables	**Pre-test CCTST**		**Pre-test science**
	Experiment group	Control group	
Pre-test CCTST	1	1	
Pre-test science	0.006	0.588	1

Pearson's product-moment correlation tests demonstrate that there is a strong, positive correlation between critical thinking skill and students' performance in science subject for both schools, school A's experiment group ($r = 0.519$, $p < 0.05$) and school B's control group ($r = 0.588$, $p < 0.05$).

4.3 Summary of findings

To summarize the results of the research questions, there is a significant difference found in the performance of participants of experiment group from school B in their CCTST post-test in comparison to the CCTST pre-test (t-value 2.59 > t-critical 2.13), with p-value is lesser than the alpha ($0.02 < 0.05$). This indicates that chess instruction has positive effects on students' critical thinking and problem solving abilities. Experiment group from school B has also demonstrated a significant difference in their mathematics achievement when comparing their post-test scores with their pre-

test scores (t-value 2.62 > t-critical 2.13) and the p-value is lower than the alpha (0.02<0.05). This indicates that chess instruction is proven to be helpful for students in improving their performance in mathematics subject.

As for science subject, the experiment group from school B demonstrates a significant difference in their post-test science scores when comparing to their pre-test scores (t-value 2.54 > t-critical 2.13) and its p-value is lower than alpha (0.02 < 0.05). This indicates that chess instructions have significantly positive effects on students' performance in science. Person's product-moment correlation test shows that all groups from both schools appear to have positive correlation between critical thinking skill and mathematics performance by using CCTST mean scores and mathematics' school test mean scores ($r = 0.266, 0.444, 0.636$, $p < 0.05$). However, the experiment group from school B shows a weak, negative correlation with $r = -0.194$, $p < 0.05$. For science scores, experiment group from school A ($r = 0.519$, $p < 0.05$) and control group from school B ($r = 0.588$, $p < 0.05$) demonstrate positive correlation between critical thinking skill and performance in science subject.

Table 4.18 summarizes the findings for this study. As we can see, experiment group from school B demonstrates significant differences in their results, which they scored higher in the post-test than their pre-test. However, experiment group from school A did not show significant improvement in their results, similar with their control group. The inconsistency of results occurred in the experiment group is discussed in the next chapter.

Table 4.18: Summary of findings

Research question	School A		School B	
	Experiment group	**Control group**	**Experiment group**	**Control group**
CCTST	No significant	No significant	Significant	No significant
Mathematics	No significant	No significant	Significant	No significant
Science	No significant	No significant	Significant	No significant
Correlation between CCTST and mathematics	Positive	Positive	Negative	Positive
Correlation between CCTST and science	Positive	Positive	Positive	Positive

There are important points that need to be addressed in this section that is results for this study need to be presented according to schools; School A and School B. This is due to several reasons:

1) Both schools located at different geographic proximity thus possess different sets of teachers who teach mathematics and science subjects. Different teachers use different approach of teaching. This factor might affected students' performance in their science and mathematics scores
2) Both schools are different type of schools (School A is a normal government elementary school; School B is an Islamic elementary school). This factor need to be considered since there might be other enrichment activities in either school that will affected participants' performance.

CHAPTER 5: DISCUSSION

5.1 Introduction

This study is conducted to determine if chess instruction could improve students' critical thinking and problem solving skills. In this chapter, the discussion would examine the answers to this study's research questions, interpret, and explain the meaning of the results. Specifically, the relationship between the game of chess and critical thinking, science, and mathematics would be discussed. This chapter begins with a brief summary on the methods used to carry out the study. After that, there would be an overview of the results of the study in light of prior research and how this work could be contributed to the prior research. For this matter, results of prior study would be discussed and compared. Then, the limitations of the study would be addressed, followed by implications for practice regarding chess, critical thinking, science, and mathematics. Finally, some recommendations and suggestions for future research on improving the research methodology would be discussed in the last section of this chapter.

5.2 Brief summary on the methodology

This study was conducted in the form of empirical, causal-comparative design. This method was chosen in an attempt to explore the effects of chess instruction on dependent variables, namely CCTST, science scores, and mathematics scores. To start the intervention, it is important to determine the independent and dependent variables involved. This is because both variables would determine the research design and suitable statistical analysis method to answer the research questions. For this study, the

independent variable is the chess instructions conducted throughout this study, while the dependent variable is students' scores in the California Critical Thinking Skills Test (CCTST) during pre-experiment and post-experiment.

This research design is inspired by Gobet and Campitelli (2005) arguments on the concept of 'ideal experiment' which include the implementation of pre-test and post-test in an experiment to assess the impacts of intervention on experimental subjects. This study refers to the intervention of chess in a traditional learning environment at school. They argue that pre-test is a substantial variable to examine differences between the assigned experimental and control groups. Any conclusion made out of the results must consider all differences detected, if there is any. Christiaen (1981) as cited in Gobet and Campitelli (2005), used only post-test approach and found no reliable effects in any Piagetian tasks and in any of the subtests administered in his study. Christaen (1981) did not use pre-test to prevent the children feeling suspicious that they were part of an experiment. Although he mentioned possible contamination in the study could be the influence of teacher who was aware of the study, Gobet and Campitelli (2005) argues that,

> "…given the lack of a pre-test, it is possible that there were difference between the two groups at the outset of the experiment." (p. 13)

Another way to control the difference between experiment group and control group is by assigning the participants randomly which is difficult to be carried out in this study. There are two reasons for that, one is that the study is conducted during school hours, thus, parents have the rights to not allowing their children get involved in the study – this is when convenient sampling is most suitably applied. The other one is that there is no other way to reach the participants outside school hours due to lack of available free time by participants and that would affect their parents' schedule to drop

and fetch them from the chess class. Due to that reasons, this study has to satisfy the features of a quasi-experimental design.

Creswell (2008) argues that most educational researchers use quasi-experimental design because of the availability of the participants or because the setting prohibits the formation of artificial groups. An example given in the argument is that when studying new mathematics program, researcher could use existing fourth-grade classes and assign one class as the experimental group and the other one as the control group. Randomly assigning students to the two groups would disrupt classroom learning (Creswell, 2008). This is exactly what had happen in the real setting of this study. In this case, Creswell suggests that a pre-test should be administered to both groups so that researcher is aware of any threat that might exist to validate the study.

Based on the methodology used for this study, this chapter displays a table of summary adopted from Gobet and Campitelli (2005) that explains the comparison of the experimental design used in few other studies related to chess with the 'ideal experiment' concept. For the purpose of this study, the table is extended to include some recent studies for a more comprehensive reference.

For this study, seventy six participants were chosen from two schools in two suburban districts located in the middle west of Peninsular Malaysia. Participants were distributed into groups using convenient sampling, based on the written consent given by their parents. As the study used some of their normal school hours, participants were

permitted to withdraw from the study at any time they wanted to. Because of this, the number of participants in both groups is not equal, unlike true experiment design.

Both experimental group and control group did not possess prior skills regarding chess and had never attended any professional training in chess. The experiment group was given chess instruction 90 minutes a day, one day a week for ten weeks.

For this study, all participants took a mathematics and science pre-test and post-test, as well as a critical thinking test called the California Critical Thinking Skills Test (CCTST). The scores between the experiment and control groups were compared using quantitative statistical method.

Table 5.1: Eight selected studies in compared of the 'ideal experiment' (Gobet, 1976)

	Random allocation	**Pre-test**	**Post-test**	**Control group I (placebo)**	**Control group II (do-nothing)**	**Different teacher and tester**	**Subjects blind to the experiment**
Ideal experiment	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Christiaen (1976)	Yes	No	Yes	No	Yes	Yes	Yes
Fried and Ginsburg (undated)	Yes	No	Yes	Yes	Yes	Yes	Yes
Frank (1979)	Yes	Yes	Yes	No	Yes	Yes	Yes

Table 5.1, continued:

	Random allocation	Pre-test	Post-test	Control group I (placebo)	Control group II (do-nothing)	Different teacher and tester	Subjects blind to the experiment
Ferguson (1995)	No	Yes	Yes	No	Yes	Not mention	Not mention
Liptrap (1998)	No	Yes	Yes	No	Yes	Yes	Yes
Hong (2005)	Yes	Yes	Yes	No	Yes	Yes	Not mention
Pearson (2008)	No	Yes	Yes	No	Yes	Not mention	Not mention
Barrett (2010)	No	Yes	Yes	No	Yes	Not mention	Not mention
Berkley (2012)	Yes	Yes	Yes	No	Yes	Not mention	Not mention

*placebo – control group but used other game than chess.

5.3 Review of the results

In this section, discussion would be steered according to the hypotheses tested in this study. The argument begins with chess and critical thinking skill, followed with chess and students' performance in mathematics, and chess and science.

5.3.1 Chess develops critical thinking skill

The study aims to explore the effects of chess instruction on participants' performances in critical thinking, science, and mathematics scores. Results reveal that there is a significant difference between the performance of participants in experiment group and control group from school B in their critical thinking test. It is shown that participants in the experiment group score higher in their post-test in comparison to their pre-test; a difference of 3.0 points increment in the mean scores during their post-test from their pre-test. This is consistent with Robert Ferguson's four-year study which reveals that non-chess enriched students increase an average of 4.56 percent annually in

Watson-Glaser Critical Thinking Appraisal while chess enriched student improve their points by 17.3 percent (Grant, 1993).

Another study that supports the result on chess and critical thinking is Johan Christiaen's study at Assenede Municipal School, Belgium which was conducted from the year 1974 to 1976. The study consisted of forty fifth-grade students with average of 11 years. His research question was to explore whether chess-enriched environment is able to accelerate the transition from concrete level which is stage three, to the formal level which stage four, based on Jean Piaget's theory of cognitive development. In stage four, students started to do hypothesizing and deducing by developing more complex logic and judgments. At the end of the study, it was proven that chess group showed significant difference between the two groups, experiment and control, in favor of the chess players (Ferguson, 1995).

Figure 5.1: The comparison of CCTST scores before and after chess intervention on participants from school A.

Figure 5.1 is a chart comparing pre-test and post-test scores of control group and experimental group for school A. The control group's mean score for pre-test of CCTST is 72.5 (SD = 4.25). At the end of the chess experiment period, the group's final CCTST

mean score is 71.1 (SD = 3.61). Although the difference is small, which is only 1.4 points, it is clearly seen that the score is declining from 72.5 points at the beginning of the study to 71.1 points at the end of study. The experimental group, on the other hand, has demonstrated a rather different figure. Prior to the chess instruction program, experimental group has a mean score of 68.7 (SD = 2.81) in their CCTST. After several series of learning to play chess, the experimental group has gained 0.6 points in their overall mean score which makes their final CCTST mean score of 69.3 (SD = 2.89).

Although the difference is small and was statistically analyzed as not significant by the *t*-test, it could still be concluded that the experimental group has the potential to gain more points in the future. In this case, longer period of chess instructions or more frequent chess lessons in a week at school might help to increase the figure. The result produced by school A conforms to a study conducted by Brandefine (2005) on the visual-spatial skills of children who play chess. In Brandefine's study, 16 male and 14 female children with average age of 9 played chess for at least 3.1 hours per week. Subjects were tested using a standardized test, Wide Range Assessment of Visual Motor Abilities (WRAVMA). One of the hypotheses tested in this study was that students who play chess would score above the average score of the WRAVMA than students who did not. The result exhibited a trend in the scores by children who play chess; they score higher than the average score of WRAVMA.

However, when the result was analyzed using *t*-test, it did not appear statistically significant (Brandefine, 2005). In this study, on the other note, school B demonstrates a different scoring pattern. Experimental subjects show a huge difference in their post-test scores as compared to their pre-test scores. Before the chess experiment, both

experimental and control subjects have a mean score of 71 (SD = 4.03, 4.61) respectively. At the end of the chess experiment period, experimental group demonstrates a mean score of 74 (SD = 3.08) and control group has a mean score of 70 (SD = 4.70). Experimental group's subjects have demonstrated a difference of 4 points in their mean score which is statistically significant by the *t*-test (α = 0.05). See figure 5.2 to compare the difference between groups.

Figure 5.2: The comparison of CCTST scores before and after chess experiment on participants from school B.

The results produced by school B have approved earlier academic researches that highlight significant improvement in students' thinking skills when they are exposed to the arts and strategies of playing chess (Unterrainer et al., 2006; Sigirtmac, 2011). Sigirtmac used quasi-experimental design with six-year-old students in Adana, Turkey. He discovered that children who play chess have better grasp with concepts such as 'forward-backward', 'between-next to', 'in front-behind', 'diagonal', 'far-near',

'corner', 'reverse sequencing', and 'pattern' than children who never played chess. For the first research question, it could be concluded that chess is a positive factor in the cognitive development of children especially in enhancing their critical thinking skills.

5.3.2 Chess facilitates mathematics learning

Malaysia has been taking part in the international achievement measurement of mathematics and science, the Trends in International Mathematics and Science Study (TIMSS) since 1999. Despite the fact that Malaysian students' average score is ranked 10th, its average Mathematics score has never been significantly higher than those other ten countries below it (Ismail, 2009). Hence, the Malaysian government is committed to reduce the gap through various initiatives in developing students' abilities in mathematics as well as critical and problem solving skills. The main objective of this study is to investigate the potential relationship between chess instruction being utilized at school and the achievement of students in mathematics subject, as measured by their end-of-the-year grades. Two research questions would be covered for this particular discussion pertaining to the connection established between chess and mathematics;

Question i: Does playing chess improve critical thinking test scores of the experiment group?

Question ii: Does playing chess increase mathematics test scores of the experiment group?

Participants' performances in mathematics test during pre-test and post-test were analyzed. Experiment group in both schools show increment in their scores, although experiment group in school B performed better in their mathematics than school A; a difference of 5.06 points during post-test in comparison to their pre-test. This difference

is significant at $p = 0.02$ ($\alpha = 0.05$) and $t = 2.62$ [2.13]. In determining the correlation between critical thinking skills and mathematics, Pearson's product-moment correlation shows consistent correlation for both experiment and control groups from the two schools, although a weak and negative correlation is found in experiment group from school B ($r = -0.194$). Correlation test was conducted using participants' CCTST and mathematics pre-test scores.

The result demonstrated in this section is consistent with Barrett's study (2010) in improving achievement of mathematics subject for students who receive special education services using chess. Moreover, Barrett discovered that even though experiment group received less exposure to the general mathematics curriculum in thirty instructional days than the control group, the students still outperformed the control group in all eight measures of mathematics' achievement tested on them (Barrett, 2010). He argues that this findings show that the loss of regular mathematics lessons could, in the very least, be compensated by the chess lessons. Christiaen (1976) suggestion is also in support of Barret's argument (Barrett, 2010).

Also, this study supports Farhad Kazemi and Ali Mohammadi (2012) study on mathematics and chess skills. He found a strong correlation between meta-cognitive ability and mathematics problem solving power. The study consisted of 86 school-boy students from various levels of age ranging from fifth to ninth-grade at primary and junior high schools in the west of Iran. His Pearson's correlation test showed a strong (0.719), positive, and significant relationship at $p < 0.01$ level. Independent *t*-test comparing mathematics score between experiment and control groups shows significant difference in experiment group's mathematics result when being compared to control

group (fifth grade p = 0.03, eight grade p = 0.01, ninth grade p = 0.004). Furthermore, Farhad Kazemi and Ali Mohammadi (2010) believe that chess creates a strong belief system in an individual as an effective problem solver. Students who learn to play chess would be able to face difficult problems and not getting disappointed or frustrated because chess has the modality to create such environment (Farhad Kazemi & Ali Mohammadi, 2012).

5.3.3 Chess and students' performance in science

As far as research is concerned, there were similar studies pertaining to this issue, they were on chess and abstract reasoning and problem solving (Celone, 2001), chess and the transfer of problem solving skills (Rifner, 1992), chess and cognitive transfer (Atherton, 2007), chess and visual-spatial skills of children (Brandefine, 2005), cognitive effects of chess instruction (Hong, 2005), as well as chess and non-verbal reasoning (Pearson, 2008). Most of the studies used standard international assessments like TONI-3, CCTST, WGCTA, et cetera. They were specially designed to measure students' ability to solve problems and their reasoning skills, not using school's science examination scores as conducted in this study.

On the other hand, students should constantly be engaged in inquiry learning and investigation approaches in order to effectively grasp the concepts in science and mathematics which have rich connections with many disciplines of knowledge and issues in real life. The ability to memorize facts, procedures, principles, and definitions as dispensed by the teachers and textbooks are no longer adequate. They should be able to analyze, interpret ideas, synthesize, and argue different concepts and contents while learning science subject at school. In this case, chess is argued to be a good tool in

developing students' critical thinking and problem solving skills. This study was conducted to explore its potential on participants' experiences in learning science.

From the result projected in this study, it is found that there is no significant increment on participants' mean scores in science test. However, we should not ignore important findings from the results depicted by experiment group from school A. The participants in that group have managed to obtain higher score during their post-test as compared to their pre-test. Additionally, Pearson's product-moment correlation test shows a positive correlation between critical thinking skill and performance in science for all participants involved (Brandefine, 2005). There is also a strong and positive correlation found in experiment group for school A ($r = 0.519$, $p < 0.05$) and control group from school B ($r = 0.588$, $p < 0.05$).

Based on these results, it is concluded that there is no significant difference in participants' science scores, although there is a positive correlation between students' performance in science and their critical thinking skill. This is consistent with study conducted by Brandefine (2005) which investigates the effects of chess on visual-spatial skills. His study shows no significant difference between chess skills and visual-spatial subtest of Wide Range Assessment of Visual Motor Abilities (WRAVMA). However, data of the study supports its two hypotheses: (1) children who play chess score above the mean score in the WRAVMA; (2) children who play chess longer hours per week show greater difference in their WRAVMA mean score than children who engage in lesser hours of playing chess.

However, the study has been criticized for several limitations that could have affected the results and statistical significant of the data obtained. One of the limitations

is its small sample size of 30 children. This factor might cause an error in exploring the correlations suggested in the hypotheses. Another one is the small number of children in each group. Significant comparisons between age of subjects, gender, hours played per week, and score on the visual-spatial subtest of the WRAVMA are difficult to achieve (Brandefine, 2005). Another factor contributed to the inconsistency of result of this study leads to Hong's study in 2005 on the effects of chess instruction on students' cognitive skills. Participants involved are students who are at risk for academic failure.

Based on Hong's study, researcher believes that chess players at any level of chess skills could experience and practice higher order cognitive skills. Results of the study show that there are no strong cognitive effects of chess instructions. The performance of experiment group in that study is no different than the performance of the control group (Hong, 2005). The inconsistency in the results is explained by the following interpretations.

(i) Students at risk require more time for chess instruction than a twelve-session chess instruction period for one semester. This is based on Pogrows (1988) model that suggests enough time and resources are key factors to develop competencies in providing solutions on difficult tasks that require higher order thinking process. Twelve-session chess instruction period might have been too short to have strong salutary cognitive effects on students at risk.

(ii) Novice chess players could hardly develop their cognitive skills until they reach a certain level of chess skills. This argument is consistent with the case that a degree of connection between chess skills and cognitive skills depend on the level of competency of chess players (Hong, 2005).

Based on the two studies that show no significant effects of chess instruction on students' cognitive and visual-spatial skills, it could be interpreted that the inconsistency of results in this study occurs between the game of chess and science achievement might be because of small number of sample, more hours of chess instruction is needed by participants every week, as well as the chess lessons must be developed according to level of education of participants, for example whether it is for high achievers or gifted students, or students at risk for academic failure.

Sample size for this study is due to limited assistants available for this study within specific funding from research grant. This is because every assistant involve receive allowance for their works. Chess instruction for this study is limited to ten weeks because researcher needs to cope with other school activities that have been scheduled by the ministry of education. Thus that is the only time slots available for this study. Different chess lessons for different level of education for participants involved requires extra chess lessons for the study which is too ambitious within the time and research funding allocated for this study.

5.4 Implications on transfer of learning

The theory of cognitive transfer is the underpinning framework of this research. Chess is perceived as a good pedagogical tool in developing students' critical thinking skill and problem solving ability. This argument is supported by a study done by Brandefine (2005) that shows connection between chess and students' visual-spatial skills. The study revolves around the hypotheses that children who spend more hours in playing chess score higher in their Wide Range Assessment of Visual Motor Abilities (WRAVMA). This helps them a lot in polishing a good set of thinking skills especially

in learning Mathematics at school. In addition to that, as a response to Brandefine (2005) study, an initiative to implement chess as a compulsory course at school has been conducted in Romania recently.

In his study, the chess group consisted of twenty novice chess students from third-grade and fourth-grade. They received one chess training session per week for ten weeks in a row. Evaluation of the program found that students preferred the board against the computer and they liked best class on 'checkmate' rather than learning about the pieces. This findings indicate that students prefer learning with high interactivity, which involves discoveries and explorations on the problem solved. Other than that, the most important finding in this study is that this initiative has led to further development into one year course of chess (Baubeg et al., 2013).

Moving on, this present study is an attempt to develop critical thinking and problem solving skills on the basis of arguments and researches that have already been discussed in this section. Measuring the occurrences of transfer of learning from chess instruction to answering critical thinking test is considered as potential which yet to be covered in this study. Given that all subjects are at the same age, attended schools within similar socioeconomic areas, received the same curriculum standard, and received the same number of hours of instruction on daily basis, it is reasonable to argue that chess is the only differing factor in the life of the subjects. Therefore, this condition has caused a difference in the critical thinking skills test's result which shows that transfer of cognitive skills has occurred.

5.5 Limitations of study

In interpreting the results of this study, one should consider several limitations that have occurred. The first one is the sample of study. This study used non-randomized sample of fourth-grade students in two schools located in the area of Klang Valley. Since this study requires participants to spend some of their curriculum period for chess class, voluntarily participation is needed. They were also needed to be in the study for the whole school year or so even though they could withdraw from the study at any time they wanted to. This caution is noted since most experimental research designs require random sampling to be used for statistical analysis purpose, in which this study used quasi-experimental design (Gobet & Campitelli, 2005).

It is also can be seen clearly that control group from both schools shows no significant difference in their critical thinking, mathematics and science scores. This finding is important to acknowledge as there are many factors that contributed to such phenomenon. One of the factors is that control group participants might be below average level of students in that school. Students who are below average level are also posses lower learning skills which will demonstrate on their academic scores.

Another reason might be from the psychological aspect. It is argued that chess is able to enhance player's self-esteem and confidence (Dauvergne, 2000; U.S. Chess Trust, 2008). It is argued that there is positive relationship between acquisition of a success experience and academic achievement setting. Therefore, there is a possibility that students who play chess have higher confidence level when compared to control group, in which this situation will affect their performance in academic.

As far as the selection of samples is concerned, the samples chosen in this study were also limited to two schools located in the area of Klang Valley. Both schools have similarity in terms of the curriculum being applied, socioeconomic background of participants, and the facilities provided. Hence, the conclusion made for this study could be generalized only to the schools or students with similar characteristics or features. Another limitation is that participants in this study were not blinded to the experiment. This is one of the hardest elements to control due to certain administrative issues and ethical reasons. As explained in the early chapter, guardians were given letter of consent to inform the involvement of their children in the study. Therefore, they were aware that they were part of a chess instruction group than their peers in the other classes.

Another constraint is that chess instruction periods were limited to only ninety minutes in a period of ten weeks. Bart (2004) as cited in Hong (2005) suggests that chess instructions should be conducted preferably for the whole academic year or at least two consecutive years to guarantee the effectiveness of learning. In this viewpoint, it is reasonable to say that more time spent on learning about chess facilitates in the development of cognitive capabilities (Brandefine, 2005). Lastly, one needs to be aware that critical thinking capabilities measured in this study is limited to what has been defined by the California Critical Thinking Skills Test – M Series. This edition has been developed to test students from elementary school. Thus, the skills tested in this study were limited to the development of cognitive abilities of children within their age range. The self-regulation skill as defined by the Delphi Panel of Expert Consensus on Critical Thinking in 1990 for example is not included in the test.

CHAPTER 6: CONCLUSION

6.1 Introduction

This study has been conducted to explore the potential of chess in enhancing students' critical thinking and problem solving skills as measured by the California Critical Thinking Skills Test, mathematics, and science scores. The significant gains in critical thinking scores achieved by the chess experiment group over the control group show that chess is a significant tool in developing participants' critical thinking skills. This study also want to know whether the gain in critical thinking scores has direct impact on students' mathematics and science scores. This is based on the arguments by Mangiante (2013) that state scientific knowledge requires higher order thinking skills for students to understand the world around them;

> "As science education reform has evolved, the next generation of science standards has emphasized students' higher-order thinking through practices of reasoning, problem solving, discourse and debate…" (p. 223)

Moreover, The Alberta Program of Studies for Science Education (2003) has incorporated critical thinking skills with clearly delineated provisions for students to critically examine issues and questions that arise from scientific phenomenon. The four foundations for building learning experiences that address the critical aspect of science and its application include; (a) science, technology, and society; (b) knowledge; (c) skills; and (d) attitudes.

> "Of particular interest is an attitude, since it is seen as the vehicle for implementing the concept of scientific critical thinking and ethics." (Gunn, 2008, p.166)

Next, both critical thinking and higher order thinking are argued as being the fundamental aspects of scientific discoveries, that the skills should be infused and nurtured through formal education (Gunn, 2008; Mangiante, 2013). Gunn (2008) also believes that attitude is one of the main keys to be developed within each student in order for them to be a good scientist. It is the foundation for critical thinking and good ethical conducts in the field of science. The habits of mind in science include exploring new discoveries, dealing with issues of uncertainties, and creating solutions to problems for the benefits of mankind. These are the qualities of true scientists. In this case, chess has already been known by many for years as an instrument or tool to enhance good thinking skills and leadership qualities.

International assessments on science and mathematics like TIMSS and PISA have been conducted since early 1990's that aim at comparing students' educational achievements of the participated countries to learn the experiences of others in designing effective educational policy. Malaysia is one of the participants and has been ranked as one of the twenty countries with the lowest scores together with Montenegro, Kazakhstan, Jordan, and Indonesia in PISA 2012 (OECD, 2014d). In TIMSS, Malaysian students' score are constantly below the international average score; Mathematics – 440, Science – 426, International Average – 500. This is based on the results released by TIMSS in 2011 (Ministry of Education, 2013).

According to these reports, it is sounds to say that Malaysia needs to plan its educational approaches and policies to meet the international requirements especially in terms of improving the quality of teaching and learning mathematics and science. In this

case, more researches and investigations must be conducted to explore the appropriate teaching methodologies and instructional strategies that would lead to the efficiency in teaching and learning science and mathematics at school. Thus, this study uses the following research questions to explore the potential of chess as an instructional method to develop critical thinking and solving problem skill.

Research questions are answered through participants' achievements in California Critical Thinking Skills Test (CCTST) as well as school's mathematics and science scores after fourteen weeks of chess lessons during normal schooling hours. Participants are aware of the study due to the pre-test and post-test study design conducted. The following is a systematic diagram showing the basis of arguments and the empirical design of this study.

6.2 Insights from the findings

This part of the conclusion chapter would discuss and provide a synthesis of the empirical findings from the study with respect to the individual research questions. Each empirical finding would be supported by arguments based on previous theories or studies concerned. The first research question addressed the impact of chess on students' critical thinking skills as measured through the California Critical Thinking Skills Test (CCTST). Experiment group from both schools have demonstrated gains in the scores in contrast to control group; school A with a gain of 0.6 points higher during post-test than pre-test while school B gains 3.0 points higher during post-test than pre-test. As suggested by Ferguson (1995) and Brandefine (2005), this study shows that chess could facilitate in the enhancement of critical thinking skills of students.

Moreover, as a strategic game, chess is a game that could be repeated for few times. This would encourage players to analyze their moves in each round (Graber, 2007). Although a player is subject to lose in a game, he or she would learn from mistakes, practice their reflective thinking, and improve their ability to think strategically, leading to better performance in the future. The second issue discussed in this study is on the relationship between chess and mathematics. This study has explored whether the game of chess could enhance participants' mathematics performance, and the correlation between chess and mathematics. The results show that experiment participants' performance in mathematics subject from both schools has increased during their post-test.

On the other hand, with similar result in CCTST, experiment group from school B has higher difference in their scores when the post-test is being compared to the pre-test than experiment group from school A. This result has proven that chess could be a powerful factor in developing students' mathematics skill. It supports previous studies that have shown similar result (Barrett, 2010; Farhad Kazemi & Ali, 2012). The art of problem solving, as found in chess playing, is the essence of mathematical concepts. Perveen (2010) further argues that problem solving is the vehicle for learning new mathematical ideas and skills. Students without this ability would eventually be left behind in their academic performance and find it difficult to deal with everyday problems in their lives.

Next, Person's product-moment correlation test also indicates that there is a correlation between critical thinking and mathematics. Students' abstract thinking is developed when they play chess, and this type of thinking is useful in solving mathematical problems. The last issue is on students' performance in science. This study attempts to explore whether chess could enhance students' scores in science, as

well as the correlation between critical thinking and science subject. According to the results, experiment group from school A gains higher scores during post-test than pre-test, while no significant gains are found in experiment group from school B.

The result conforms to study conducted by Rifner (1992), Celone (2001), Brandefine (2005), and Atherton (2007). Although the studies do not directly measure the effect of chess on science performance, all of them addressed the skills learned during chess play that are required in scientific learning. Result of the Person's correlation found that there is a positive correlation between critical thinking and science. This shows the importance to develop critical thinking skill especially in this case, through chess to perform well in science subject. The skills to analyze, synthesis, and interpret data or arguments learned through chess could also be applied in science, especially in dealing with scientific issues.

This include some ethical issues concerned with scientific discoveries that need to be addressed appropriately by considering the effects and factors related to that issues. In spite of encouraging results, researcher observes no significant improvement in students' performance in science of all the experiment groups based on the *t*-test conducted. After considering all factors and limitations of this study, researcher agrees that small sample size, sampling assignment, and limited period of study might be the cause of this inconsistency. However, it is found that experiment group from school A shows a potential in its scores.

6.3 Policy implication

Attempts on various approaches to develop students' critical thinking and problem solving skills must be encouraged continuously. The reducing number of

graduates in science and engineering courses worldwide for example, has called upon various parties across the globe to address this issue. The 'No Child Left Behind' act in the United States and The Alberta Program of Studies for Science Education in Canada are some of the initiatives taken by the governments to tackle the issue. Both programs incorporate critical thinking aspect in science and mathematics subjects, requiring students to use their analytic skill, interpret ideas, and synthesis solutions to problems.

These are the learning programs that do not simply based on memorizing facts and theories. Students conduct their scientific lessons in the classroom while teachers serve to facilitate the instructions. Lessons would also be conducted through problem-based learning, discussion, and dialogue about related issues. For this matter, chess is a good tool in providing ample problems to be solved in the classroom. Students would start to come out with their arguments, discuss among themselves, and suggest their own ways to checkmate their opponents. Besides that, due to the fact that chess itself is a game, teaching and learning process at school would become more enjoyable that simultaneously turn out to become an educational tool.

Self-confidence, motivation, and self-discipline are also among many good qualities that gradually being built during this activity. It is a great advantage if chess and other educational games could be incorporated in school's curriculum in Malaysia. By providing at least one period of classroom learning weekly for the children to play chess, we could further explore significant increment in their academic performances. As has been proven through literature review, chess does not only increase students' performances in science and mathematics, but also improve other skills such as reading, music, as well as attention and memory span of an individual.

6.4 Recommendations for future research

It is discussed in the first chapter of this study that small number of participants, non-random sampling assignment, and limited time of study are some of the limitations of this study. However, a small number of participants allows researcher and research assistants to give enough focus on each participant while facilitating them throughout the lessons in fourteen weeks. With a more appropriate number of research assistants and time length of study, future research should consider increasing the number of participants in order to get results that are statistically significant.

Finally, this study was conducted in ten weeks due to the waiting time to get permission from the schools involved and from the ministry of education. Process includes waiting for approval letter from both parties and consent forms from all parents whose their children were involved in the study. It would be an advantage if future researcher is able to conduct all the legal and ethical procedures one year earlier to prevent this bureaucratic issue. Other than that, random sampling is good sampling method in any experimental research as it gives statistically significant results for a study. Participants are assigned randomly to experiment and control groups resulting equal number of participants in each group.

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