LEARNING, PRACTISING AND COMPETING IN CHESS: A STUDY INVESTIGATING THE RELATIONSHIP BETWEEN CHESS IN SCHOOLS AND STANDARDISED LITERACY AND NUMERACY SCORES

A Thesis submitted by

Graeme Charles Gardiner
MPSR

For the award of

Doctor of Professional Studies

2025

ABSTRACT

This doctoral study investigates the relationship between students who have progressed beyond the beginner level in chess and their performance on standardised literacy and numeracy assessments (NAPLAN) in Queensland, Australia. The research is grounded in a systematic and scoping literature review of 393 studies, revealing a fragmented field and a notable gap in research linking chess proficiency with academic outcomes. While prior studies, such as those by Sala and Gobet (2016, 2017a, 2017b, 2017c, 2018), question the existence of far transfer effects from chess to academic domains, this study builds on emerging evidence suggesting that chess rating, rather than mere participation, may be a critical factor influencing academic performance. Adopting a postpositivist paradigm, the study employed a quantitative, explanatory design. Chess proficiency was operationalised through rating-based groupings (novice, rookie, intermediate, advanced), while academic achievement was measured using NAPLAN scores across five domains: numeracy, reading, grammar and punctuation, writing, and spelling. Advanced statistical analyses, including MANOVA, ANOVA and t-tests, were conducted to test the study's hypotheses. Findings indicate a statistically significant relationship between higher chess ratings and improved performance in spelling, writing and particularly numeracy. Furthermore, schools with a stronger chess culture, measured by the proportion of rated players to school population, demonstrated significantly higher average scores across all five NAPLAN domains. These results suggest that chess, when practised and competed in beyond the beginner level, may contribute to far transfer effects, especially in numeracy, thereby offering pedagogical value for schools seeking to enhance academic outcomes through extracurricular programmes. The study also identifies future research directions and raises questions about the influence of school types and chess culture on academic achievement. As a Doctor of Professional Studies (DProfSt) thesis, the research contributes not only to educational practice but also to the candidate's development as a reflective practitioner-scholar, with a reflexive account of professional growth included in the concluding chapter.

CERTIFICATION OF THESIS

I Graeme Charles Gardiner declare that the Thesis entitled ***Learning, practising and competing in chess: A study investigating the relationship between chess in schools and standardised literacy and numeracy scores*** is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This Thesis is the work of Graeme Charles Gardiner except where otherwise acknowledged, with most of the contribution to the papers presented as a Thesis by Publication undertaken by the student. The work is original and has not previously been submitted for any other award, except where acknowledged.

Date: 6 November 2025

Endorsed by:

Professor Luke van der Laan Principal Supervisor

Associate Professor David Smerdon Associate Supervisor

Student and supervisors' signatures of endorsement are held at the University.

ACKNOWLEDGEMENTS

"There are between 10^{78} to 10^{82} *atoms in the observable universe. The number of possible chess games is much higher: somewhere around* 10^{120} *different positions as calculated by the American mathematician Claude Shannon (Shannon, 1950). There are roughly 85 billion different ways to play the first four moves alone. The Shannon number is at least one reason a sport that has been played for more than 1,500 years continues to arrest imaginations across all cultures with the unceasing promise of infinite potential, all within those 64 tiny squares".* (Graham, 2024, https://www.theguardian.com/sport/2024/nov/23/world-chess-championship-2024-ding-liren-v-gukesh-dommaraju-pre-match-questions-answered)

I acknowledge with my most sincere gratitude the input, backing and encouragement of my supervisor, Professor Luke van der Laan, throughout my Certificate of Professional Studies, Master's Degree and now Doctoral Study. He was an inspiration throughout, and I can't speak highly enough of him. I also acknowledge with warm thanks the valued assistance of Associate Professor David Smerdon, who came on board more recently. I also acknowledge with thanks the assistance of my wife, Wendy Gardiner, who gave constant support, especially in terms of editing, over the entire journey. Thanks also to Karen Crowley, who enthusiastically tutored me through the statistical analysis.

Others who provided assistance I'd like to acknowledge are Steven Cooke, Shaun Curtis, Professor Patrick Danaher, Andrew Fitzpatrick, Andrea Harris, Justine Jule, John McGuire, David McKinnon and Doug Williams.

This research has been supported by the Australian Government Research Training Program Scholarship.

DEDICATION

I am thankful for the opportunity to dedicate this Doctoral Thesis to two outstanding women: my wife, Wendy, and my late colleague, Christina Wand. Wendy has never failed to support me in many ways, over several years, especially when the going was hard. As a retired schoolteacher and chess player, Christina was always interested in the project and liked to read the work and make suggestions. When I needed a teacher to interview many primary school students, she stepped in. Along with my supervisor, Professor Luke van der Laan, these two fine women were an inspiration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ACE	Automated Case Elicitation
ACF	Australian Chess Federation
ACT	Acceptance and Commitment Theory
ADHD	Attention Deficit Hyperactivity Disorder
AI	Artificial Intelligence
ANCOVA	Analysis of Covariance
APR	Age Performance Relationship
ASD	Autism Spectrum Disorder
BAARS-IV	Barkley Adult ADHD Rating Scale
BDEFS	Barkley Deficit in Executive Function Scale
BFQ-C	Big Five Model
BKT	Binet–Kamat Test of Intelligence
CAQ	Chess Association of Queensland
CBR	Case-Based Reasoning
CDP	Chess Development Project
CHREST	Chunk Hierarchy and Retrieval Structures
CICL	Children in Conflict with the Law
CogAT	Cognitive Abilities Test
COVID-19	Coronavirus Disease of 2019
CPRS-HI	Abbreviated Conner's Rating Scales
CRT-V	Verbal Cognitive Reflection Test
CSS	Chess Self-Efficacy Scale
CWMT	Cornoldi's Working Memory Test
DMA	Decision-Making Automatism
DMD	Decision-Making Dynamism
EEG	Electroencephalograms
ELO	International Chess Rating
EPAM	Elementary Perceiver and Memoriser
ESM	Electrical Stimulation Mapping
FAB	Field-Specific Ability Beliefs
FIDE	Fédération Internationale des Échecs (World Chess Federation)

FPI-R	Freiburg Personality Inventory-Revised
GSES	General Self-Efficacy Scale
HBDI	Hermann Brain Dominance Instrument Test
LASSI	Weinstein and Palmer's Learning and Study Strategies Inventory
LBOTE	Languages Other Than English
MANOVA	Multiple Analysis of Variance
MATE	Move On Strategy and Tactics Dataset
MBCR	Mindfulness-Based Stress Reduction
MMSLQ	Mathematics Motivated Strategies for Learning
MPC	Model Predictive Control
MRI	Magnetic Resonance Imaging
NAPLAN	National Assessment Program – Literacy and Numeracy
NNAT	Naglieri Non-Verbal Ability Test
ODD	Oppositional Defiant Disorder
PAR	Participatory Action Research
PPP	Practice-Plasticity-Processes Model
PSE	Prediction and Self Explanation
PSS	Pre-Stored Schema
PSSG	Cassidy and Lang's Problem-Solving Style Questionnaire
QCAA	Queensland Curriculum and Assessment Authority
QJRL	Queensland Junior Ratings List
RL	Reinforcement Learning
RPSM	Ravens Standard Progressive Matrices
SASC	Social Anxiety Scale for Children
SEM	Structural Equation Modelling
SEN	Special Educational Needs
SES	Self-Esteem Scale
SNAP-IV	Swanson, Nolan and Pelham Scale
TAAS	Texas Assessment of Academic Skills
TAKS	Texas Assessment of Knowledge and Skills
TAMAI	Self-Report Test
TDCS	Transcranial Direct Current Stimulation
TOL	Tower of London Planning Test

TOM	Theory of Mind
TONI-3	Nonverbal, Language-Independent Test
TTCT	Torrance Test of Creative Thinking
USCF	United States Chess Federation
WCST	Wisconsin Card Sorting Test
WISC-IV INDIA	Wechsler Intelligence Scale for Children
WISC-R	IQ Test
WKCT	Wallach-Kogan Creativity Test

CHAPTER 1: INTRODUCTION

1.1 Introduction

This large-scale study, inspired by Poston and Vandenkieboom (2019), examines the relationship among school students' learning, practising and competing in chess, and the possible benefits for their thinking skills as measured by literacy and numeracy test scores. The existence of "far transfer" has recently been challenged (Sala & Gobet, 2016, 2017a, 2017b, 2017c, 2018), and this study extends the investigation of the relationship among learning, practising and competing in chess, and standardised literacy and numeracy test scores.

The topic of children learning chess and their cognitive skills has been well-researched. However, various meta-analyses have found only occasional small benefits, if any, and most studies have yet to show the necessary level of academic rigour. Apart from Poston and Vandenkieboom (2019), studies have yet to examine specifically the phenomenon of children learning, practising and competing in chess well beyond just learning to play the game.

A postpositivist, quantitative, confirmatory study using secondary large-scale data from the Queensland Junior Ratings List (QJRL) and the National Assessment Program – Literacy and Numeracy (NAPLAN) standardised test scores from the Queensland Curriculum and Assessment Authority (QCAA) was designed to extend the Poston and Vandenkieboom (2015) line of enquiry. Analysing these longitudinal data over 15 years makes it possible to measure the progress of non-chess players, rookies, and intermediate and advanced chess players through their school years and what, if any, relationship this has with their standardised literacy and numeracy test scores. Further, any difference there may be between these groups can be demonstrated.

This chapter outlines the study's background (Section 1.2), context (Section 1.3), purposes (Section 1.4), significance, scope and definitions (Section 1.5), stakeholder perceptions justifying this study, including Paper 1 (Section 1.6) and an overview of the remaining chapters (Section 1.7).

1.2 Background

Chess, believed to have originated in India circa 500-600 CE (Eales, 1985, p.13), is a popular game worldwide. At the 2024 chess Olympiad held in Budapest, 186 national teams were represented in the open event and 167 in the female tournament. In Queensland, Australia, approximately 7,000 students in approximately 350 schools play regular organised chess. Each year, during Terms One, Two and Three, regional interschool teams' qualifying competitions are held around Queensland, involving 3,000-4,000 students, culminating in the state final in October and the national final in December.

For many years, researchers have been interested in the possible benefits of learning chess for students. A primary reason for this interest is to inform educational policy and delivery more effectively.

1.3 Context

The primary focus of this study is to investigate whether children who take chess beyond the beginner level to learning, practising and competing benefit from improved literacy or numeracy scores and, if so, at which level that benefit occurs.

The only large-scale study conducted in this domain by Jerrim et al. (2016) in the UK looked mainly at beginners and found no benefits for the players' standardised test scores. The level of chess knowledge of beginners was insignificant in its relationship to standardised test scores. Once they start practising and competing in chess, their chess knowledge increases. Through their playing regularly in competitions, two things happen. Firstly, the competition helps them retain the ideas they are learning, and secondly, they receive feedback through chess ratings (indications of playing strength).

The state of research on children learning chess and its possible benefits for their standardised test scores has almost reached a standstill. Seminal researchers Sala & Gobet (2016, 2017a, 2017b, 2017c, 2018) have concluded that research investigating the impact on standardised test scores should cease, as positive results are improbable. However, with positive findings, Poston and Vandenkieboom (2019) were the first researchers to have studied students learning, practising and competing beyond the beginner level.

This study acknowledges Sala and Gobet's (2016, 2017a, 2017b, 2017c, 2018) findings and seeks to extend the Poston and Vandenkieboom (2019) line of enquiry. Owing to the size of this confirmatory study (which importantly includes many students who have taken chess well beyond the beginner level), the number of years covered and the range of chess abilities, a gap in the research field is addressed.

1.4 Purposes

The study aims to provide clear evidence of whether children learning, practising and competing in chess gain additional benefits in standardised literacy and numeracy scores and, therefore, whether this is evidence of far transfer of skills.

This research answers the overarching question, "Does playing chess, as measured by extra learning, practising and competing by Queensland school students, have measurable educational benefits regarding standardised test scores?"

The study tests quantitatively whether there is a correlational or causal relationship among chess instruction, practice and competition, and higher literacy and numeracy scores. The research methods and sample size were designed to provide rigorous results and to build on previous studies on this topic.

1.5 Significance, Scope and Definitions

Like many other chess-playing colleagues, the researcher contends, from his direct experience and from anecdotal evidence, that playing chess helps children with their thinking skills. Based on a 2016 survey conducted by Gardiner (2018), stakeholders such as school principals, schoolteachers, parents of children learning chess and companies providing chess instruction services also share this perspective. However, to date, there has been little supporting evidence.

The study takes up the opportunity to replicate the study of Poston and Vandenkieboom (2019), which used longitudinal data from only one school and reported promising results regarding children learning, practising and competing in chess. The researcher also examined longitudinal data, but with a larger sample size of rated chess layers and with more variables from multiple schools.

Statistical methods were applied to a de-identified merged secondary dataset of NAPLAN scores, chess ratings (playing strength) and chess activity (number of rated games played). These included descriptive statistics, correlations, multiple analysis of variance (MANOVAS) and t-tests. The effects by groups, including age, gender, languages other than English (LBOTE) and type of school, were also analysed.

The research may also contribute significantly to the debate about whether “far transfer” between domains exists and under what circumstances this may occur.

The following concepts are relevant to the study and are defined below:

Beginners – those students learning to play chess at a very low level – i.e., learning to move the pieces correctly and how to capture. Jerrim et al. (2016) describe this level as learning the basic rules of chess, what makes a good move, simple checkmates, basic tactics and checkmating techniques.

Novices (practising and competing) – those students who have played in their first chess tournament and received their first chess rating (Queensland Junior Chess Rating of 500-799).

Rookies (practising and competing) – those students who have been practising and competing for some time and have played in junior and/or adult tournaments with chess clocks and scoresheets (Queensland Junior Chess Rating of 800-999).

Intermediate (practising and competing in championship events) – those students who are used to playing in tournaments with long time controls (e.g., 60 minutes a side or more), often in the company of titled junior and adult chess players (i.e., national masters, international masters and grandmasters) (Queensland Junior Chess Rating of 1000-1199).

Advanced (practising, competing and featuring in championship events) – those students who are used to playing and winning or placing in tournaments with long time controls, often in the company of titled junior and adult chess players (i.e., national masters, international masters and grandmasters) (Queensland Junior Chess Rating 1200+).

Unlike nearly all previous studies, this study did not predominantly investigate primary school children learning to play chess at a basic level (Beginners). Instead, it concerns children receiving chess instruction, practising and competing in tournaments from Grades 1-9 over several years.

To start, a survey of stakeholders, primarily school principals, teachers and parents of children learning chess, was conducted to inform the next steps of this study.

1.6 Stakeholder Perceptions Justifying the Study

The researcher conducted an exploratory study of stakeholder perceptions of the educational benefits of chess as no previous studies had investigated these to any extent, despite these being valuable indicators of possible benefits. Based on stakeholder perceptions, further research and modified lines of enquiry can be justified as is the case with the direction adopted in this study.

Chess is widely available in schools globally, due to its perceived academic benefits. Many policy makers, educators and parents advocate for its inclusion as a co- or extra-curriculum activity. Stakeholders' beliefs that chess in schools contributes to education improvement is apparent in the positive advocacy and growth of chess as part of education systems.

The literature suggests numerous and diverse benefits, but studies that seek to provide a holistic perspective of the nature and extent of these benefits are scarce. Previous studies have mostly focused on the impact of learning to play chess in relation to standardised literacy and numeracy test scores with researchers questioning whether this is a viable line of enquiry. Perception studies that adopt a stakeholder theory perspective is helpful when confronted by seemingly ambiguous or 'tricky' issues such as that of attributing educational benefits to chess. Indeed, education research recognises the importance of understanding stakeholder perceptions in all educational improvement initiatives.

1.7 Conclusion

Chapter One has presented the study problem, background and relevant literature that framed this study's lines of enquiry. It also set out the study's purpose, aims and approach. The chapter also presented the findings of a sub-study that investigated stakeholder perceptions of the educational benefits associated with playing chess. This sub-study, together with the gap in the literature, was used as justification for the study.

This chapter has introduced the study, which is followed by an initial literature review (Chapter Two), substantial literature review and scoping review (Chapter Three), methodology (Chapter Four), results (Chapter Five) and discussion and conclusion (Chapter Six).

The literature review (Chapter Three): 1) considers the parameters and conceptual clarity of previously published studies; 2) presents a review of all reported studies related to the benefits of playing chess among school students; 3) identifies gaps in the literature; and 4) culminates in a conceptual model and the research questions guiding the study.

CHAPTER 2: CHESS, CHILDREN, THINKING, THEORY AND LIFE

2.1 Introduction

Chapter One provided the background to, context of and needs justifying this study. Chapter Two sets out to provide a general overview of chess-related research as it relates to children, educational benefits, possible effects on their thinking, related theories and how playing chess may influence their social interactions. This chapter's scope is broader than the topic area but was included in the thesis as it provides a useful understanding of the entire field of research and lines of enquiry.

Chess, which has a history of over 1,500 years (Eales, 1985), is more than just a game. It has a unique culture that lends itself to research on many levels. On one level, it is a sport; on another, it is an introduction to academic study. For many, it is an outlet for competitive instincts, which may not be available owing to difficulty or challenge. Indeed, boys and girls often find their disabilities are not a barrier to chess playing, and, instead, they find great joy and satisfaction from the game. Some, like crossword addicts, just like testing their brains on every move.

The World Chess Federation (FIDE) has a "Chess in Education Commission" at https://edu.fide.com/. The evidence is that chess education is expanding rapidly, especially in countries such as China and India. As previously mentioned, the chess website *chess.com* has 219 million members as of July 2025. At the same time, *chesskid.com* claims to have 20,000 schools and 9 million students as active users. Chess in schools is growing at exponential rates around the world.

Since 2010, there has been a noticeable increase in studies relating to children learning and playing chess and to the possible resulting benefits (e.g., Martinez, 2012; Jerrim et al., 2016; Sala & Gobet, 2017a, 2017b, 2017c; Gardiner, 2018; Poston & Vendenkieboom, 2019). The range of these perceived benefits is significant, but, with a few exceptions, studies do not show sufficient academic rigour. Most involve school chess programmes, and many discuss the elusive "far transfer".

The importance of "far transfer" is a key issue in chess research. Educators are interested in teaching chess to students, which may lead to other benefits elsewhere. Many chess researchers are schoolteachers who are also chess players.

The literature reviews conducted in the field of chess and children mostly relate to literacy, numeracy and “far transfer”: Gobet and Campitelli (2006), Bart (2014), Nicotera and Stuit (2014), Gates (2015), Sala and Gobet (2016), Burgoyne et al. (2016), Exposito Barrios (2017), Ortiz-Pulido et al. (2019), Boyle and Anderson (2019), Brito (2021) and Blanch (2022).

In this systematic literature review, the two most important categories are “Seminal Works” and “Transfer”, followed by “Mainstream”, which includes Chunking Theory, Deliberate Practice, Expertise, Memorisation, Pattern Recognition, Recall, Psychology and Knowledge; and “Cognitive Processes”, which involves 23 sub-categories.

The overarching aim is to present readers with a comprehensive analysis of research to date, with sufficient information to enable them to focus on specific themes, topics or studies. Necessarily, there is some crossover and even duplication of supporting information. Readers may find some information in this work helpful for their current research. What the researcher is not doing here is: a) proving a theory; b) conducting a quantitative study; or c) showing the importance or otherwise of far transfer.

For those thinking of conducting research involving children, chess and its possible educational or other benefits, the literature review can assist in choosing a path that suits them. Papers on literacy and numeracy, which are included in the recent scoping review conducted by the same author and shown later in this thesis, are omitted.

The benefits for children learning chess are made with no exaggerated claims. The intention is to create a sense of the 'current state of play' and to show potential researchers where they might fit. More detailed information about each study can be found by following the citations. Further research is possible and potentially useful.

Table 1 provides an overview of relevant literature associated with studies on children learning to play chess and its possible effect on their education and other benefits. Ninety-two search term combinations resulted in the retention of 393 papers divided into eight categories.

Table 1: Studies on children learning to play chess and the possible educational benefits or relationships

Categories	Number of Studies	Studies identified significantly involving the subject matter	Seminal/Transfer/ Mainstream	Cognitive Processes	Key Thinking Skills	Physical, Psychological and Emotional Wellbeing	Education, Pedagogy, Didactics, Maths, Analytics and Stats	Special Needs, Difficulties, Disabilities or Disadvantages	Gender	AI and IT
Abstract Thinking	3	Celone (2001); Horgan and Morgan (1986); Laws (2014)			✓					
Acceptance and Commitment Theory	2	Ruiz et al. (2023); Ruiz and Luciano (2012)				✓				
Agreeableness	1	Bilalić et al. (2007)				✓				
Algorithmic Thinking	1	Karapetyan (2021)			✓					
Analogical Thinking	2	Cauzinille-Marmeche and Didierjean (1998); Gunes and Tugrul (2016)			✓					
Analytical Thinking	1	Stegariu and Iacob (2020)			✓					
Anticipation	1	Gobet (2018)			✓					
Argumentation	1	Peran (2019)			✓					
Artificial Intelligence	11	Anbarci and Ismail (2024); August (2024); Bilalić et al.(2024); Chole et al. (2024); Koenig (2024); Koerts (2024); Peng (2024); Tang et al. (2024); Thakur et al. (2024); Tirado and Pilatti (2024b); Poulidis et al. (2025)								✓
Attentional Ability	8	Ezennaka and Unachukwu (2023a); Gliga and Flesner (2014); Karimi and Mahmoudfakhi (2024); Louedec et al. (2019); Mijaică and Rendi (2020); Noir (2002); Stegariu and Abalasei (2022a); Velea and Cojocaru (2018)		✓						
Autism/ Neurodiversity	8	Blasco-Fontecilla et al. (2016); Bornstein and Cunningham (2023); ElDaou and El-Shamieh (2015); Karapetyan and Charchyan (2021); Ke and Moon (2018); Nechio (2016); Ruiz et al. (2023); Singh (2023)				✓				
Body Schema	2	Horgan (1987); Stegariu et al. (2022)				✓				
Calculation	5	Burjan (2017); Chang and Lane (2016); Noir (2002); Rosholm et al. (2017); Scholz (2008),					✓			
Calibration	4	Heck et al. (2024); Horgan (1987); Horgan (1990); Horgan (1992)					✓			
Categorising	1	Noir (2002)			✓					
Children in Conflict with the Law	1	Lastima and Gayoles (2020)						✓		
Chunking	10	Campitelli (2017); Gobet (2005); Gobet and Simon (1996a); Gobet and Simon (1996c); Gobet and Simon (1998); Gobet et al. (2001); Gobet et al. (2006); Leong et al. (2024a); Leong et al. (2024b); Noir (2002)	✓							
Comprehension	5	Burgoyne et al. (2016); Dapica-Tejada (2016); Gates (2015); Mamani Celiz (2020); Meloni and Fanari (2019)		✓						
Computation	2	Basson (2015); Rice et al. (2012)		✓						
Concentration	4	Atashafrouz (2019); ElDaou and El-Shameih (2015); Noir (2002); Scholz (2008)		✓						
Conceptual Thinking	2	Mechner (2010); Sigirtmac (2012)			✓					
Consonance and Dissonance	1	Mirzakhanyan et al. (2019)				✓				

Categories	Number of Studies	Studies identified significantly involving the subject matter	Seminal/Transfer/ Mainstream	Cognitive Processes	Key Thinking Skills	Physical, Psychological and Emotional Wellbeing	Education, Pedagogy, Didactics, Maths, Analytics and Stats	Special Needs, Difficulties, Disabilities or Disadvantages	Gender	AI and IT
Contextual Thinking	1	Mirzakhanyana (2017)			✓					
Creative Thinking	4	Hichem et al. (2023); Joseph et al. (2017); Joseph et al. (2021); Sigirtmac (2016)			✓					
Critical Thinking	4	Berkley (2012); , Brusamolin and Pedroni (2024); Gates (2015); Khachatryan et al. (2024)			✓					
Decision Making	3	Chacoma and Billoni (2024); Schmid et al. (2024); Szczepańska and Kaźmierczak (2022)		✓						
Deliberate Practice	16	Blanch and Colom (2023); Burgoyne et al., (2019); Campitelli and Gobet (2008); Campitelli and Gobet (2011); Campitelli et al. (2014); Chang and Lane (2018); de Bruin et al. (2007b); Ericsson (2018); Ericsson (2020); Ericsson and Harwell (2019); Hambrick et al. (2014); Krivec (2022); Noir (2002); Rimban (2023); Tenemaza et al. (2020); Trinchero and Sala (2016)	✓							
Dialogic Thinking	1	Sundaramadhavan et al. (2021)			✓					
Didactic	3	Mahmudov et al. (2020); Noir (2002); Sepúlveda-Herrera and Huincahue (2024)					✓			
Disabilities	4	Barrett and Fish (2011); Pozzi et al. (2024); Scholz et al. (2008); Singh (2023)						✓		
Divergent Thinking	2	Joseph et al. (2021); Sigirtmac (2016)			✓					
Dyslexia	1	Rello et al. (2016)						✓		
Estimation	1	Horgan (1992)		✓						
Executive Functions	5	Dania et al. (2023); Khosrorad et al. (2014); Oberoi (2021); Singh (2023); Urra (2015)		✓						
Expertise	10	Chang and Lane (2018); Costantino et al. (2024); Ericsson (2020); Fuhl and Hyseni (2024); Gobet (2006); Grabner (2014); Horgan and Morgan (1990); Pförtner and Hristova (2024); Schneider et al. (1993);Trevisan et al. (2022)	✓							
Gender	17	Arnold et al. (2023); Backus et al. (2023); Barbier (2020); Baasanjav (2017); Bilalić et al. (2009b); Blanch et al. (2015); Brancaccio and Gobet (2023); Chassy (2023); Chitiyo et al. (2023); Dilmaghani and Smerdon (2024); Ezennaka and Unachukwu (2023b); Galitis (2002); Gerdes and Gränsmark (2010); González-Díaz et al. (2024); Martínez Ramírez (2021); Noir (2002); Smerdon et al. (2023)							✓	
Heuristics	3	Campitelli et al. (2014); Mechner et al. (2013); Trinchero and Sala (2016)					✓			
Information Technology	8	Gundawar et al. (2024); Milosz and Kapusta (2024); Monroe and Chalmers (2024); More et al. (2024); Omori and Tadepalli (2024); Ruoss et al. (2025); Siven (2024); Tirado and Pilatti (2024a)								✓
Inhibition	3	Khosrorad et al., (2014); Shahar and Avital (2020); Vollstädt-Klein et al. (2010)		✓						
Intellectual	5	Glukhova (2017); Mărăcine and Mihăilescu (2023); Stegariu et al. (2019); Xalilovic (2023); Zaretsky et al. (2023)			✓					
Intuition	6	Bühren and Frank (2012); Chassy et al. (2023); Gobet (2017); Gobet and Chassy (2009); Linhares (2005); Smith (2021)			✓					
IQ	2	Grabner (2014); Stegariu et al. (2023)			✓					

Categories	Number of Studies	Studies identified significantly involving the subject matter	Seminal/Transfer/ Mainstream	Cognitive Processes	Key Thinking Skills	Physical, Psychological and Emotional Wellbeing	Education, Pedagogy, Didactics, Maths, Analytics and Stats	Special Needs, Difficulties, Disabilities or Disadvantages	Gender	AI and IT
Knowledge	5	Gobet (2006); Gobet (2017); Noir (2002); Rosholm et al. (2017); Waters et al. (2002),	✓							
Learning Difficulties and Disabilities	2	Sargsyan and Khachatryan (2024); Scholz (2008)						✓		
Logical Thinking	4	Belova (2018); Masharipova and Matyusupov (2023); Quchqorivich (2022); Stegariu and Iacob (2022a)			✓					
Memorisation	10	Ahmed and Siddique (2017); Chang and Lane (2018); Gobet (1996); Gobet (1998); Gobet and Simon (1998); Glukhova (2017); Masharipova and Matiusupov (2023); Mijaică and Rendi (2020); Noir (2002); Wall (2018)	✓							
Mental Imagery	3	Ekizoğlu et al. (2023); Noir (2002); Waters and Gobet (2008)				✓				
Mental Wellbeing	13	Capero-Escribano et al. (2024); Cheragh-Birjandi et al. (2024); Dovom et al. (2024); Fuentes Garcia and Villafaina (2024); Fuentes-Garcia et al. (2020); Lastima and Gayoles (2020); Lillo-Crespo et al. (2019); Lutfilloevna and Kumar (2024); Makhova (2017); Mărăcine and Mihăilescu (2024); Mukhamejhanova and Sadikov (2024); Sari-Sarraf et al. (2024); Singh (2023)				✓				
Metacognition	8	Ahrens et al. (2024); Horgan (1990); Kazemi et al. (2012); Kramarski et al. (2002); Meloni and Fanari (2021); Noir (2002); Sala & Gobet (2017); Tachie and Ramathe (2022)		✓						
Mindfulness	4	Ashgari (2023); Balagué i Canadell et al. (2023); i Canadella et al. (2023); Teimoory (2022)				✓				
Motivation	8	Bouacida et al. (2024); Charness et al. (2004); de Bruin et al. (2007b); De Lemios et al (2025); Kazemi (2022); Melkonyan et al. (2024); Noir (2002); Petallo and Berry (2024)				✓				
Non-Verbal Reasoning	1	Eberhard (2003)		✓						
Numeracy	2	Giouvantsioudis (2024); Malvasi et al. (2022)					✓			
Original Thinking	1	Sigirtmac (2016)			✓					
Patience	2	Islam et al. (2021); Rimban (2023)			✓					
Pattern Recognition	6	Campitelli (2017); Ferreira and Palhares (2008); Gobet (2006); Linhares and Freitas (2010); Noir (2002); Ong et al. (2024),	✓							
Pedagogy	9	de Freitas Ferreira (2023); Esau (2023); Gevorkyan et al. (2023); Jenifer et al. (2024); Masharipova and Matiusupov (2023); Noir (2002); Romanova et al. (2018); Szczepanik-Ninin (2024); Xalilovich (2023)					✓			
Perception	4	Ferrari et al. (2006); Ferrari et al. (2008); Gobet and Lane (2010); Joseph et al. (2017)		✓						
Planning Skills	1	Grau-Pérez and Moreira (2017)		✓						
Prediction	3	de Bruin et al. (2007a); Horgan (1992); Maroju et al. (2024)		✓						
Probability	4	Gerdes and Gränsmark (2010); Horgan (1987); Horgan (1992); Rodríguez-Muņiz et al. (2022)					✓			
Problem-Solving	7	Atashafrouz (2019); Celone (2001); Ferreira and Palhares (2008); Kazemi et al. (2012); Noir (2002); Rifner (1992); Sala et al. (2015)		✓						
Processing Speed	1	Joseph et al. (2018)		✓						

Categories	Number of Studies	Studies identified significantly involving the subject matter	Seminal/Transfer/ Mainstream	Cognitive Processes	Key Thinking Skills	Physical, Psychological and Emotional Wellbeing	Education, Pedagogy, Didactics, Maths, Analytics and Stats	Special Needs, Difficulties, Disabilities or Disadvantages	Gender	AI and IT
Psychology	5	Cleveland (1907); Gobet (2006); Gobet (2018); Gobet and Jansen (2006); Vaci and Bilalić (2017)	✓							
Purposefulness	1	Medvegy et al. (2022)				✓				
Rational Thinking	2	Hichem et al. (2023); Varga and Marschalko (2024)			✓					
Reasoning	5	Celone (2001); Joseph et al. (2017); Joseph et al. (2018); Wang et al. (2024); Weitl-Harms et al. (2024)		✓						
Recall	9	Barr (2024); Chase and Simon (1973); Gobet (2006); Gobet and Simon (1996b); Gobet et al. (2001); Gong et al. (2015); Noir (2002); Schneider et al. (1993); Waters et al. (2002)	✓							
Reflection	1	Ezennaka and Unachukwu (2023a)		✓						
Relative Age Effects	2	Helsen et al. (2016); Kalwij and De Jaegher (2023)				✓				
Resilience	1	Medvegy et al. (2022)				✓				
Risk Aversion	2	Carow and Witzig (2024); Islam et al. (2021),				✓				
Risk of Academic Failure	1	Hong and Bart (2006)						✓		
Science	5	Jerrim et al. (2018); Joseph et al. (2016); Thompson (2003); Uskoković (2023); Uskokovic (2024)			✓					
Self Efficacy	1	Olivo and Barbaranelli (2023)				✓				
Self Esteem	1	Jianguo et al. (2019)				✓				
Seminal Works	18	Chase and Simon (1973); de Groot (1946); de Groot (1978); de Groot (1986); de Groot and Lyman (1977); de Groot et al. (1996); Gobet (1993); Gobet (1997); Gobet (1998); Gobet (2018); Gobet and Simon (1996b); Gobet and Simon (2000);Jongman (1968); Simon (1983); Simon (1986); Simon and Chase (1988); Simon and Newell (1971); Simon and Simon (1962)	✓							
Social Reasoning	1	Smith (2021)				✓				
Socio-Emotional	2	Aciego et al. (2012); Aciego et al. (2016)				✓				
Spatial Ability, Concept, Orientation	1	Stegariu and Iacob (2022)		✓						
Special Needs, Special Education	3	Barrett and Fish (2011); Charchyan and Karapetyan (2022); Scholz (2008)						✓		
Strategic Thinking	4	Chitiyo et al. (2021); Meloni and Fanari (2021); Noir (2002); Salmi (2024)			✓					
Stress	3	Mukhamedjanova (2020); Purnomo et al. (2024); Stegariu et al (2025)				✓				
Subjective Thinking	1	Eisma et al. (2024)			✓					
Theory of Mind	3	Bailey (2002); Sigirtmac (2016); Trevino (2019)		✓						
Thinking Patterns	3	Bilalić et al. (2010); Hichem et al. (2023); Joseph et al. (2017)			✓					
Transfer	31	Barrett and Fish (2011); Bart (2014); Basson (2015); Blanch (2022); Campitelli (2017); Chitiyo et al. (2021); Dall'Osso Teigset (2023); Gardiner (2018); Hammond (2014); Hermelin (2010); Horgan (1992); Joseph et al. (2020); Karakuş (2023);	✓							

Categories	Number of Studies	Studies identified significantly involving the subject matter	Seminal/Transfer/ Mainstream	Cognitive Processes	Key Thinking Skills	Physical, Psychological and Emotional Wellbeing	Education, Pedagogy, Didactics, Maths, Analytics and Stats	Special Needs, Difficulties, Disabilities or Disadvantages	Gender	AI and IT
		Krivec (2022); Meloni and Fanari (2019); Meloni and Fanari (2021); Noir (2002); Perkins and Salomon (1992); Rifner (1992); Rosholm et al. (2017); Sala & Gobet (2016); Sala & Gobet (2017a); Sala & Gobet (2017b); Sala & Gobet (2017c); Sala et al. (2016); Sala et al. (2019); Scholz et al. (2008); Sigirtmac (2016); Trinchero and Sala (2016); Zapounidis (2021)								
Verbal Reasoning	2	Eberhard (2003); Joseph et al. (2018)		✓						
Visualisation	1	Basson (2015)		✓						
Visually Impaired	3	Aydin (2015); Balata et al. (2015); Ekizoğlu et al. (2023)						✓		
Visuospatial	5	Gonzalez-Burgos et al. (2024); Küchelmann et al. (2024); Noir (2002); Smith et al. (2021); Waters et al. (2002)		✓						
Working Memory	3	Atashafrouz (2019); Joseph et al. (2020); Sala & Gobet (2017c)		✓						
92 Terms/ 8 Categories	**393**		10	23	24	18	7	7	1	2

Figure 1 illustrates the number of the 393 studies concluded over time. The trend clearly shows the growing, and more recently exponential, increase in chess research.

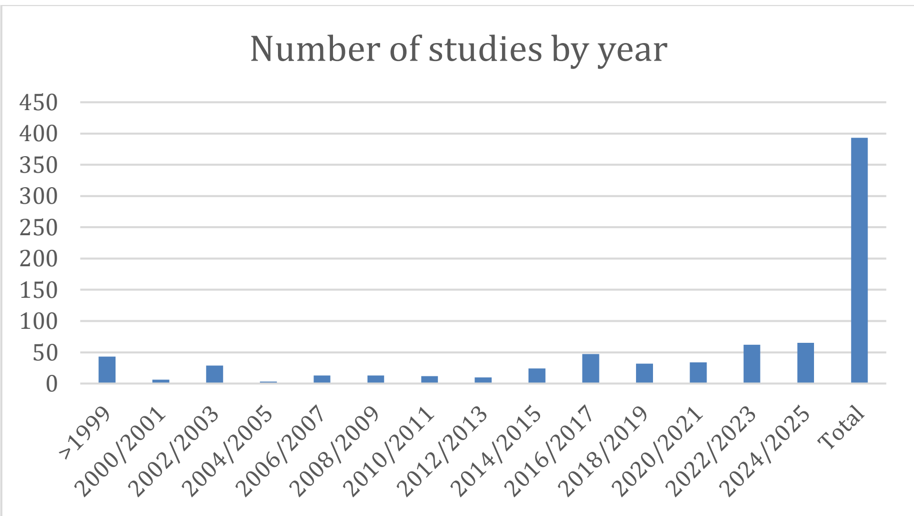


Figure 1: Number of studies by year

The most cited researchers were Gobet 32, Sala 22, Noir 20, Horgan 14 and Joseph 10.

2.2 Seminal Works/Transfer/Mainstream Theories

Seminal Works

Seminal works are initial works that present an essential or influential idea within a particular discipline. Dr Adriaan de Groot's work in the late 1930s and early 1940s, republished in 1978, examined how chess Grandmasters think and how their minds work. His doctoral thesis was translated and published as *Thought and Choice in Chess* in 1978. Many regard it as a significant contribution to psychology and cognitive science. Today, the Dutch school system still uses aptitude tests that De Groot used in his book to describe the selection process in the school system.

In the introduction to de Groot's work, Professor Sijbolt Noorda from the University of Amsterdam commented, "His research contributed substantially to the development of psychology as an empirical discipline". De Groot's (1978, p. 334) observation that a master chess player can understand large complexes because they are typical wholes to him or her, and therefore can understand the position quickly, ultimately led to chunking and template theory.

Chase and Simon (*The Mind's Eye in Chess*, 1973) introduced chunking theory, which involved segmenting memory tasks into chunks. They conceived the Mind's Eye "as a system that stores perceptual structures and permits them to be subjected to certain mental operations" (p. 266). Gobet and Simon (1996b) proposed template theory. Chunking and template theory are highlighted in Section 2.12.4.1.

To this day, Professor Gobet is at the heart of revisions to these theories.

Transfer

Researchers have been fixated on the idea that playing chess will help children do better in other endeavours, such as school studies, including literacy and numeracy. As recently as 2016, senior researchers found that skill transfer can happen, even though there are caveats regarding the precise circumstances. More recently, even the existence of transfer has become contentious and difficult to prove.

Sala & Gobet (2017a) stated, "Transfer of skills across loosely related domains remains a chimera" (2017c, p. 5), and they continued:

> *Researchers and policymakers should seriously consider stopping spending resources for this type of research. The field should clarify the domain-specific cognitive correlates underpinning expert performance rather than searching for a way to improve overall domain-general cognitive ability.*

Sala et al. (2019) conducted a second-order meta-analysis, which concluded that "no impact on far-transfer measures was observed regardless of the type of population and cognitive-training program". Blanch (2022), having conducted a meta-analysis of the statistical power of 45 studies, "raised reasonable concerns over the evidence about the benefits of chess instruction, which was particularly problematic regarding academic achievement outcomes".

Chunking and Template Theories

Undoubtedly, and as was noted above, the trailblazer in the field of chess psychology was Dr Adriaan de Groot, whose pioneering work around 1940 was published as *Thought and Choice in Chess* in 1978; Chase and Simon (1973) followed up with another significant work, *The Mind's Eye in Chess*, in 1973. They used the recall phase to define temporal boundaries and a memory task to segment the output into chunks. For a perception task, players' head movements were observed as "look back" tasks to segment the outputs into chunks (Chase & Simon, 1973, p. 218). They conceived the Mind's Eye "as a system that stores perceptual structures and permits them to be subjected to certain mental operations" (p. 266). They hypothesised that "perceptual structures and the mind's eye play a similar role in recall of moves from a game" (p. 275).

Gobet and Simon (1996) introduced template theory, the idea that many distinct templates can be stored in long-term memory with associated information about the positions of pieces. To test a complex model such as this quantitatively, Gobet introduced a preliminary model for chess memory, a computer programme with the acronym CHREST (Chunk Hierarchy and Retrieval STructures), which is still being developed in 2025. The same authors (Gobet & Simon, 1996a) noted that recognition based on superior chess knowledge plays a more significant part in high-level skill than planning by looking ahead. This is demonstrated in simultaneous chess when the proponent has little time to think ahead. They also observed (Gobet & Simon, 1996c) that comparing a computer simulation with a human experiment supports the usual estimate that chess masters store some 50,000 chunks in memory. When positions are modified by mirror image reflection, observed recall impairment implies that each chunk represents a specific pattern of pieces in a specific location.

Gobet and Simon (1998) revisited chunking theory and concluded that “the 2-second inter-chunk interval used to define chunk boundaries is robust, and that chunks have psychological reality”.

Gobet et al. (2001) observed that “recent work with discrimination-network computational models of long- and short-term memory: – Elementary Perceiver and Memoriser (EPAM) and CHREST – has produced diverse applications of perceptual chunking”.

Campitelli and Gobet (2005) noted that “irrelevant information affects chess masters only when it changes during the presentation of the target game”, suggesting the mind’s eye uses novelty information to “select incoming visual information and separate ‘figure’ and ‘ground’”.

Campitelli (2017) noted that “pattern recognition is useful for recognising positions and generating possible moves in the current position, but it is also an integral part of the search process. Instead of moving pieces in the actual chess board, chess players simulate their movement in the mind’s eye, and they recursively apply pattern recognition over the positions held in the mind’s eye”.

A study involving 20 experienced chess players and 20 inexperienced players found that, under time pressure, experienced players could improve their recall and performance by reorganising and integrating chunks of chess positions (Leong et al., 2024a). A further study by the same researchers identified topological characteristics and patterns of frontal-parietal functional connectivity, indicating a relationship between enhanced chunking processes and improved chess performance (Leong et al., 2024b).

Deliberate Practice

Campitelli and Gobet (2011) found strong evidence that the minimum level of deliberate practice required to reach the master level is 3,000 hours, and that other factors play a role in chess skills: general cognitive abilities, sensitive period, handedness and season of birth.

Chang and Lane (2018) noted that, like Ericsson's (1993) theory of deliberate practice and Chase and Simon's recognition-action theory, 10 years or 10,000 hours are required to achieve master level. They also noted in a separate study involving 77 adult chess players that time spent studying at home and engaging in other activities was strongly related to chess skills. However, other factors, including domain-general fluid intelligence, domain-specific fluid intelligence and domain-specific crystallised intelligence, all contributed substantially to the prediction of chess ratings even after controlling for practice and other chess-related activities. These findings support the view that studying alone and playing chess are necessary, but that more is needed to achieve a very high level of chess performance.

Data were gathered through a questionnaire survey from 21 participants at a chess tournament in England (Tenemaza et al., 2020). "Results indicate that those with a growth mindset for chess ability had longer serious study sessions and those with an intelligence growth mindset participated in more serious competitions". The researchers concluded that "educators should consider that a student's performance in their academic setting may be affected by a mindset category".

Although they believed that deliberate practice was an essential factor in chess expertise, Hambrick et al. (2014) also considered starting age, personality, IQ and genes to be necessary factors.

Campitelli et al. (2014) challenged the belief that deliberate practice and IQ are solely responsible for high-level chess achievement by introducing the practice-plasticity-processes (PPP) model, which incorporates neural plasticity and cognitive processes (domain-specific pattern recognition and heuristics) as explanatory variables".

Burgoyne et al. (2019) used Structural Equation Modelling (SEM) to reanalyse data from Charness et al. (2005). They included data on "serious starting age" and "number of chess books owned", which were not measured by Charness. Burgoyne indicated that all measured domain-specific experiences left 36.6% of the variance in peak rating unexplained. Using different statistical methods, "deliberate practice" (or "serious study") was the strongest predictor of chess skill. Burgoyne concluded that “future studies should include measures of cognitive ability, informal instruction, parents’ skill level, coaching quality, and the use of other training aids such as online databases”.

A study by Blanch and Colom (2023) involved chess ratings data from 72,022 chess players from 170 nations collected over seven years. They showed that “talent predominates over practice for explaining the achievement at the highest levels in chess expertise (excellence) as assessed by objective performance scores”. They concluded that the evidence supports the theory that, in the chess domain, natural talent prevails over deliberate practice.

Expertise

One definition of “expertise” is “special skill or knowledge acquired by training, study or practice in a particular field”. Ericsson (2020) noted that, although deliberate practice is one of the most critical contributors to expertise, other types of practice also contribute and should be differentiated and named.

As previously noted in Section 2.12.4, Chang and Lane (2018) acknowledged Chase and Simon’s recognition-action theory and Ericsson’s theory of deliberate practice

Grabner (2014) revealed that studies involving psychometric intelligence tests have concluded that “expert chess players display significantly higher intelligence than controls and that their playing strength is related to their intelligence level”.

Constantino et al. (2024) found that significant periods of unsupervised training may be necessary to achieve greater behavioural congruence between human behaviour and expert models. The effectiveness of the research dataset in “distinguishing between expert and non-expert chess players” was corroborated.

Fuhl and Hyseni (2024) presented a conference paper arguing that chess is an excellent vehicle for studying “expertise classification based on eye tracking data” because they have only visual information available.

A Bulgarian study by Pförtner and Hristova (2024) questioned how events unfold as a game proceeds in real time. The results add to our knowledge of the relationship among chess expertise, cognitive skills and event segmentation.

Trevisan et al. (2022) claimed that their study added to the "evidence that chess expertise is based on the complex properties of the brain surface of a network of transmodal association areas important for flexible high-level cognitive functions".

A UK study by Ong et al. (2024) proposed a new way of quantifying the complexity of chess patterns. The authors claimed their method could help understand why the "interplay of dynamic patterns and their outcomes is essential for deriving actionable insights".

A study from New Zealand using the computer programme Stockfish examined the concept of "expertise-induced amnesia" and its relationship with automaticity and the acquisition of skill (Barr, 2024).

Knowledge

According to Gobet (2006), knowledge is an essential issue in the study of expertise. He later examined the role of knowledge in expertise (Gobet, 2017). "Generally, chess programs rely on search more heavily than knowledge; for humans, it is the reverse. However, each can achieve high-performance levels because knowledge and search can trade off" (as cited by Gobet, 2006).

Gobet (2017) notes that education and philosophy have a common interest in knowledge: "While philosophy has enquired on the nature of knowledge and its truth value, education has focused on transmitting knowledge through teaching". Different philosophical answers will result in different educational practices. Three views agree about the difficulty of transfer of skill: Dreyfus and Dreyfus (1986) because intuitive knowledge is context-dependent; Montero and Evans (2011) because advanced heuristics are domain-specific; and Gobet and Chassy (2009) because knowing-how is linked to specific perceptual knowledge.

Noir (2002) endeavoured to set up his series of studies involving children learning chess in a way that had the maximum possibility of encouraging transfer. He questioned which teaching didactics should be used to encourage and maximise the efficient transferability of skills from chess to other cognitive domains. Noir went to great lengths to explore the relationship between the knowledge base and chunking. He surmised that high-level knowledge appears essential in the perception of a position to be memorised with a view to its recall. The primary interest in this work was to highlight the importance of the links between deep exploration capacity and building the long-term, memory-stored knowledge base.

Memorisation

Gobet and Simon (1996) examined the relationship between memory and players' ability to reconstruct random games and miscellaneous distorted positions. Computer simulations compared with human experiments supported the theory that chess masters store around 50,000 chunks in their memory. The same researchers noted evidence of templates (large retrieval structures) in long-term memory (Gobet & Simon, 1998).

A longitudinal study in Russia (Glukhova et al., 2022) entitled "Chess for Overall Development" ran from 2004 to 2017 and involved 870 Grades 1-9 students from six schools in Satka City. The researchers reported that the chess for overall development group scored higher than the control groups for visual and aural memory at 0.000**.

A study from Uzbekistan (Masharipova & Matiusupov, 2023) used a four-month study involving pedagogical observations of 20 primary school students to build a chess teaching programme as "an effective tool for developing memory".

Noir (2002) observed that, while Gobet and colleagues focused on the constructs of expertise, he looked at the students, how their memory and subsets of memory are refined, and how their cognitive processes are developed.

A Romanian study by Mijaică and Rendi (2020) involved 39 children aged 6-7, 13 of whom systematically practised chess for an hour a week for 26 weeks, 13 of whom systematically practised chess for two hours a week and 13 of whom played no chess. The results indicated that the group that practised chess for two hours a week scored significantly better in memorisation tests than the group that practised it for one hour. Both groups scored significantly better than the "no chess" group.

Pattern Recognition

A Portuguese study by Ferreira and Palhares (2008) involving 437 Grades 3-6 students found that, in contrast to other students, chess players are better at numerical patterns than geometric patterns. While chess players identify numerical patterns better than non-players, most students prefer geometric patterns to numeric patterns.

Linhares and Freitas (2010) contributed to the computational development of CHREST by proposing a change in philosophy from “pattern recognition” to “experience” recognition.

Psychology

Cleveland (1907) noted:

The most important psychological feature in the learning of chess (and it seems equally true of all learning), is the progressive organisation of knowledge, making possible the direction of the player's attention to the relations of larger and more complex units.

Vaci and Bilalić (2017) note that the German National Chess Database, which has collected data from over 130,000 chess players over 25 years, “offers a rich and complete collection of the skill, age, and activity of the whole population of chess players in Germany”. The database opens opportunities for research involving factors that underlie expertise and skill acquisition.

de Groot conducted sessions between 1938 and 1943 with some of the world’s greatest chess players on how they think. His thesis was hard to find, but it was eventually published as *Thought and Choice in Chess* in 1978.

Gobet (2018), who conducted a study with de Groot in 1996, observed that “it [chess] has sometimes been called the *Drosophila* of cognitive psychology, by analogy to the role of the fruit fly in genetics”. In 2019, he published a book, *The Psychology of Chess*, which can be regarded alongside de Groot’s thesis as the definitive work in chess and cognitive psychology.

Recall

Chase and Simon’s 1973 seminal work noted that, when chess masters and weaker players looked at random chess positions, recall was equally poor for masters and weaker players. However, when looking at a ‘normal’ chess position, the masters were significantly quicker and more accurate. Later, Gobet et al. (2001) noted that “these findings presented such a vivid illustration of the principle that knowledge is the key to expertise that it has become a classic finding, widely cited in cognitive psychology textbooks and papers on expertise".

Schneider et al. (1993) replicated several of Chi's (1978) classic results. They found that strong child chess players were much quicker at recalling meaningful chess positions than adult novices. Also, the children's digit spans (memory tasks) were lower than the adults. In comparison, the delayed recall of novice chess players corresponded to their immediate recall, while the experts recalled more delayed than immediate recall.

Gobet and Simon (1996c) observed that recall is impaired when chess positions are altered using a mirror image reflection, implying that "each chunk represents a specific pattern of pieces in a specific location".

Gong et al. (2015) introduced a new chunking identification method, the "repeated recall technique". They conducted a study that tested improving chess players and a group who had never played chess. Significant differences were found between the two groups in the characteristics of chunks recalled in game positions. The size of the most significant chunks among chess players correlated with chess skill.

2.3 Cognitive Processes

Attentional Ability

A study from Romania by Stegariu and Abalasei (2022b) involved two groups of 10 third-grade students (chess and control). Two tests were applied: the Bender-Santucci test (spatial orientation); and the Kraepelin and Toulouse-Pieron tests (attentional abilities). The chess group recorded better results and a moderate correlation between spatial orientation and attentional abilities.

Another study from Romania (Mijaică & Rendi, 2020) involved three randomly chosen groups of 13 students. Group One was "do nothing", Group Two did chess for an hour a week and Group Three practised chess for two hours a week for 26 weeks. Group Three performed best, and Group Two performed second best in memory, attentional ability and understanding text tests.

A Nigerian study (Ezennaka & Unachukwu, 2023b) involved 203 Anambra state students who participated in a chess study for 160 minutes a week for six weeks. The Mindful Awareness Attention Scale was used, and the researchers concluded that playing chess enhanced attention skills.

A French study (Louedec et al., 2019) used convolutional neural networks to predict chess players' visual attention. Task-driven data and data augmentation indicated that chess players' visual attention can be predicted.

Twenty Romanian primary school students in the chess group and 18 who did fun maths lessons participated in a study to measure the effect of chess training on school performance, creativity, sustained attention and memory (Gliga & Flesner, 2014). Most cognitive tests improved in both groups, but the school performance test improved significantly more in the chess group than in the control group.

Velea and Cojocaru (2018) conducted a study in Bucharest, Romania that involved 29 primary school students aged 6-11 from urban and rural areas who undertook chess weekly for six months. Kraepelin, Bourdon-Anfimov and Toulouse-Pieron tests were used to focus on attention. "Most subjects improved their focused attention, and very few subjects did not show a significant difference between the pre- and posttest results."

A study by Karimi and Mahmoudfakhi (2024) investigated a possible relationship between Transcranial Direct Current Stimulation (TDCS) and controlled visual attention/response in serious chess players.

Comprehension

Meloni and Fanari (2019) conducted a study in Cagliari, Italy, involving 85 nine-year-olds. Of these, 48 were randomly assigned to a chess group (which received 30 hours of chess training) and 37 to a control group (which undertook a sports programme). No difference was found between the two groups on comprehension tests.

A study in the Madrid region of Spain (Dapica-Tejada, 2016) involved 60 12-year-olds, of whom 30 were regular chess players and 30 were not. The tests used were the PROLEC-SE test battery of reading processes and the King-Devick saccade test. Results indicated that the chess students performed slightly better than the control group on reading comprehension ($p=0.12$) and significantly better on saccades (0.01).

A UK study by Burgoyne et al. (2016) conducted a meta-analysis of the relationship between cognitive ability and chess skills. One of the findings was that chess skills correlated positively and significantly with comprehension knowledge.

Mamani Celiz (2020) conducted a study in La Paz, Bolivia that investigated and found positive results for teaching chess to six-year-old children to improve their reading comprehension.

Gaudreau (1992) conducted a study in New Brunswick involving 437 fifth graders that lasted nearly two years, from September 1990 to June 1992. The group that took the chess-enriched maths curriculum recorded a 12% better standardised test result than the control group that did not include chess.

Computation

Waters and Gobet (2008) provided evidence about the interaction between chunking theory and mental imagery "to test the predictions of a well-established computational theory of expertise". Simulations were run using the CHREST model (Gobet & Simon, 2000).

Basson (2015) spent part of her Masters thesis discussing the computational complexity of chess. For example, she noted that "certain researchers believe that understanding the cognitive and computational processes associated with a complex domain such as chess, and an analysis of expertise in the domain, will open a window into the mechanisms of mind". In the early years of her studies, Basson conducted an experiment involving 64 children aged 4.5 to 6 years. The chess group (34) received 40 x 30-minute sessions of chess instruction over four terms at Garsfontein Primary School in South Africa, and the control group (30) did nothing. The results suggested that chess instruction exerted a (small) positive effect on performance intelligence and, subsequently, on the Global scale of the Junior South African Intelligence Scales. Also, both groups exhibited improved cognitive development after 40 weeks in 2009.

Concentration

A study by Scholz (2008), reviewed elsewhere in this systematic literature review, found no evidence of children learning chess showing increased concentration skills. In contrast, a Lebanese study by ElDaou and El-Shameih (2015) involving 14 children aged 11-13 with Attention Deficit Hyperactivity Disorder (ADHD) showed improved concentration measurements using Conner's Teachers Rating Scale: Revised-Long version. Supporting this, the experimental group of 20 10th grade maths students who participated in four months of chess training in Ahvaz, Iran significantly improved their concentration skills compared with the "do nothing" control group (Atashafrouz, 2019).

Decision Making

A Polish study by Szczepańska and Kaźmierczak (2022) aimed to develop a procedure to use information from millions of chess games played at online chess sites for "geospatial social analysis". Decision-making traits can be studied to gain a better geographical analysis, especially for assisting decision-making relating to (for example) economic, educational, health, political and social issues.

A study by Chacoma and Billoni (2024) used a chess engine to evaluate positions in chess games and players of differing playing abilities. The researchers found that a decrease in complexity may result in lower player performances, whereas an increase in complexity may result in more accuracy in player moves.

Schmid et al. (2024) investigated whether large language models can be taught by training on chess data to generate valid chess moves, thus indicating their use in other decision-making and strategic domains.

Estimation

Dianne Horgan wrote several papers on chess and children between 1986 and 1992. The Horgan (1987) paper briefly examined expertise, heuristics, calibration, "satisficing", process feedback and probabilities. Horgan asked, "How can children, before reaching the formal operations stage, think so logically?" She noted that elementary school children demonstrated extraordinary accuracy in estimating win probability in games versus rated chess players, even though they did not know probability theory or standard deviations.

Executive Functions

An Iranian study in Tehran (Khosrorad et al., 2014), involving 20 Grades 4/5 students with and without maths disorders who were randomly assigned to "chess" and “control” groups, examined the effect of chess instruction on maths scores and executive functions. Both groups were administered the Stroop, Continuous Performance and Tower of London (TOL) Tests. The chess group was taught two one-hour chess lessons per week over a school year, and the control group was not. The positive findings led the researchers to conclude that “chess training can be very promising to improve executive functioning and mathematics performance of students with dyscalculia”.

A study from Havana, Cuba by Urra (2015) involved conducting a bibliographic review that identified the “basic theoretical components of executive functions in chess players”: activation, attention management, effort maintenance, emotions management, flexibility, goals, impulse inhibition, memory management, metacognition and planification. The aim was to provide sports psychologists in Mayabeque Province with a tool to evaluate the executive function of chess players.

Oberoi (2021) conducted a study in Houston, USA involving 39 students (aged 8-17) from beginner groups of chess academies across the USA who undertook a 14-session chess intervention. The single group, pretest/posttest design used three measures of executive function: Iowa’s Gambling Task - decision making; Digital Span Backward Task – Working Memory; and Barratt Impulsiveness Scale – Impulsivity. Paired-sample t-tests indicated statistically significant differences in decision-making and working memory but no significant difference in impulsivity. The researchers claimed that chess interventions can improve executive function in youth, which may have positive academic, health and work-related outcomes.

A randomised study from western India (Singh et al., 2023) involved 60 chess players and 60 non-players aged 11-16. The players had been playing chess at least five days a week for five years, including formal training in an academy for one year. Testing revealed that, unlike non-players, the chess group demonstrated “better and advanced cognitive functions, selective attention, executive functions, working memory, single reaction time, choice reaction time and IQ”.

Twenty-six 19-20-year-old invasion-game athletes were randomly assigned to a group that participated in a 10-week chess training programme (13) and a do-nothing control group (13) (Dania et al., 2023). The results indicated improved working memory, selective attention and decision-making for the chess group but not for the control group.

Inhibition

Shahar and Avital (2020) from Israel conducted a study published in a Russian journal. This study involved 107 Israeli boys, average age 12, 55% of whom were diagnosed with ADHD (25 of these were on medication) and approximately 25% of whom were on a gifted programme, and who completed an online questionnaire. “Whereas some scholars differentiate between impulsivity and inhibition as distinct elements, for the current study, we conceptualised them jointly; namely, that a high level of impulsivity means a low level of inhibition.” The researchers concluded that, regardless of diagnosis, although causality was not established, results showed that “chess players were less impulsive than non-chess players”.

A German study by Vollstädt-Klein et al. (2010) examined the personality profile of elite chess players. Using the Freiburg Personality Inventory-Revised (FPI-R), it was found that elite male chess players were more inhibited, while the opposite was found for elite females. While male personality profiles matched population norms, females were happier, had fewer physical concerns and were more motivated.

Metacognition

An Italian study of 85 children (Meloni & Fanari, 2021) comprised 48 in the chess group, which received 30 hours of chess training, and 37 in the control group that carried out a sports programme. Neither group improved metacognitive skills. In contrast, an Iranian study by Kazemi et al. (2012), which involved 86 children randomly chosen for the chess group and 94 also randomly chosen for the control group, found that chess can potentially improve metacognition in learners. A South African study by Tachie and Ramathe (2022) involved 25 in the chess group and 26 in the non-chess control group. It concluded that “chess training improves teachers’ and learners’ application of metacognition in supporting learners’ performance in mathematics**”.**

Noir (2002) included a substantial section on metacognition in his thesis. He noted:

> *[I]f a metacognitive function is mobilisable, independent of the field of expertise of the task, and if a strong interaction exists between the field of*

expertise and the procedural metacognitive capacities, then the question of a didactic intervention in terms of metacognitive transfer during the construction of the expertise becomes relevant and must be studied.

An Italian study by Sala and Gobet (2017a) involved 233 third and fourth graders, including active and passive control groups, receiving 25 hours of chess instruction. No statistically significant difference in metacognitive abilities or mathematical problem-solving in the posttest was found. These results support the growing evidence that the concept of far transfer is unlikely.

In research from Latvia and Germany, Ahrens et al. (2024) examined the possible benefits for disadvantaged groups of playing chess for their metacognitive skills and social inclusion.

Non-Verbal Reasoning

A study by Eberhard (2003) involving 137 students from the economically disadvantaged region of South Texas found statistically significant results for non-verbal reasoning for all chess students, including those who were economically disadvantaged. Non-chess students did not obtain statistically significant results.

Perception

A study involving 43 children (28 boys, 15 girls) who underwent chess training for an hour a week for a school year and 42 in the control group (26 boys, 16 girls) from two private schools in South India utilised three sub-sets of the Wechsler Intelligence Scale for Children (WISC-IV INDIA) for measurements of perceptual reasoning. The chess group showed statistically significant improvements compared to the control group, establishing a positive correlation between perceptual reasoning and learning chess (Joseph et al., 2017).

Gobet and Lane (2010) demonstrated the importance of perception in chess. The domain of chess was the first use of a computer application known as “CHREST”. It has proved helpful in engaging cognitive abilities such as decision-making, memory, perception and problem-solving. The key theme described by the authors is that cognition is perception. They also describe a symbolic system that integrates learning with perception. Central to how a model of the mind might look could be a two-way interaction between cognition and perception.

Ferrari et al. conducted two French studies (2006 and 2008). The 2006 study examined the perceptual processes of master chess players, which highlighted the anticipatory component of expert perception. The 2008 study examined the perceptual processes of chess players in their domain of expertise, resulting in the early encoding of non-strategic familiar patterns, followed by more strategic patterns.

Planning Skills

Tests conducted in Germany using a Tower of London (TOL) planning test by Unterrainer et al. (2006) found that chess players were more accurate than non-players on problem-solving tasks, which increased with difficulty. Using the same task in 2011, the same authors found no differences between chess players and non-players. This was because, in the initial study, chess players (and not the non-chess players) were advised that they were being compared with non-chess players, while this was not the case in the second study.

A study from Uruguay (Grau-Pérez & Moreira, 2017) involved 28 children aged 7-12, 14 of whom had already received chess instruction for at least a year and 14 of whom had never received any chess instruction. The groups were matched for age and gender. A planning test (TOL) and a cognitive flexibility test, Wisconsin Card Sorting Test (WCST), were administered. The chess group performed better on TOL and flexibility.

Prediction

Forty-five first-year psychology students in Holland who had never played chess and did not know the basic rules agreed to participate in a 'rook and king' endgame study and were randomly assigned to one of three conditions. Some chess instruction was provided, including legal moves for king and rook, basic checks, checkmates and capturing. Specific details of the chess training were provided. The development of principled understanding was described, and self-explanations were recorded (de Bruin et al., 2007a). Participants who displayed prediction and self-explanation (PSE) showed a better understanding of the principles involved in rook and king endgame than those who predicted without explanation. It was concluded that the PSE group developed a considered understanding, allowing them to "transfer learned principles to a novel task".

Horgan (1992) examined students' predictions alongside their calibration, which she defined as "the accuracy with which students can predict their performance". She noted that students' ability to predict task performance had not been studied much. Horgan's study found that efficient study habits were associated with better calibration and performance.

Situation awareness, which involves cognitive tasks such as prediction, comprehension and perception, is essential for safety in certain situations (for example, air traffic control). Various tests indicated that the stronger chess players made fewer errors (Maroju et al., 2024).

Problem-Solving

Unsurprisingly, several researchers have conducted studies involving children learning chess and their problem-solving skills, as every move in a game presents a new problem. A Portuguese study by Ferreira and Palhares (2008) involved 437 Grades 3-6 students and the relationship between their chess playing level and their problem-solving patterns. A weak positive relationship was established between problem-solving patterns and school grades (particularly maths). The chess group was better with numerical than with geometric patterns.

A study from Connecticut, USA (Celone, 2001) involved 19 elementary school students aged 7-14 who chose to participate in a week-long chess programme, and who were tested on the Test of Non-Verbal Intelligence (TONI-3) and the domain-specific Knight's Tour. A significant increase was recorded between the pretest and the posttest for IQ and domain-specific problem-solving scores.

Sala et al. (2015) conducted a study in Northern Italy involving 560 students (chess 309, control 251) from 31 Grades 3-5 classes in eight schools. The chess group undertook 10-15 hours of chess instruction and online training, while the control group did the usual school activities. Results indicated that the chess group strongly correlated with mathematical problem-solving, showing more improvement than the control group.

Atashafrouz (2019) conducted a study in Ahvaz City, Iran, which investigated the relationship between 40 Grade 10 students (20 "chess" who did 15 chess sessions, and 20 “control” who did normal activities), and the following tests were applied: Cassidy and Lang’s problem-solving style questionnaire (PSSG); Cornoldi’s working memory test (CWMT); and Weinstein and Palmer’s learning and study strategies inventory (LASSI). There were significant results for concentration and working memory, but not for problem-solving.

Twenty Grades 6/7 students of average and above average ability were randomly selected at a school in Indiana, USA, for one year of chess instruction (Rifner, 1992). The chess students of both ability levels successfully applied general problem-solving skills across domains, particularly poetic analysis and problem-solving skills.

Eighty-six chess and 94 control students were randomly selected to participate in a six-month study in Sanandaj, Iran (Kazemi et al., 2012). The instruments were the meta-cognitive questionnaire of Panaoura et al. (2003) and mathematics exams. The chess group performed better than the control group on meta-cognitive and mathematical problem-solving tests. Also, a significant, positive relationship was found between students’ mathematical problem-solving power and their meta-cognitive ability.

Noir (2002) noted:

> *Problem-solving heuristics have used chess calculations to investigate decision-making processes and probabilistic strategies. Especially in problem-solving, the work on metacognition has been the most numerous, given that it is a high-level cognitive activity that recruits several abilities: hypothetico-deductive, probabilistic, or inductive reasoning, planning, strategy, and inhibition. Let us add that solving problems is at the heart of school training; it is naturally a privileged subject of study in cognitive developmental psychology.*

Processing Speed

A study in India (Joseph et al., 2018) funded by the Indian government involved 88 Grades 3-9 children in the chess group, which did chess training over 12 months, and 90 in the control group, which did other extra-curricular exercises. These children were selected from four city schools. Two subtests of the Wechsler Intelligence Scale for Children (WISC-IV India) – Coding and Symbol Search – were used to measure processing speed. A significant relationship between chess instruction and processing speed was established. The authors claimed this was a significant finding as “processing speed ability contributes significantly by conserving cognitive resources and efficiently using the working memory for higher order fluid tasks”.

Reasoning

“Perceptual reasoning is the ability that incorporates fluid reasoning, spatial processing, and visual motor integration” (Joseph et al., 2017). The researchers conducted a pretest-postest study in South India involving 43 in the chess group who did weekly chess for a year and 42 in the “no chess” control group. The measuring instrument was three subtests of the WISC-IV INDIA. The chess group scored a statistically significant increase in perceptual reasoning compared to the control group. The researchers claimed that the study “establishes a correlation between chess learning and perceptual reasoning”.

Joseph et al. (2018) conducted a study that examined the effect of one year of chess instruction on children’s verbal reasoning. A pretest-postest design involved 70 eleven-year-old Grades 3-9 children in the chess group and 81 in the control (other games) from two government and two private schools. The Binet–Kamat Test of Intelligence was used for verbal reasoning. Significant gains in verbal reasoning were found in the chess group vs. the control group. A t-test for the chess group revealed a significant improvement in overall intelligence.

Based on the idea that chess players combine long-term strategic play with short-term tactics, Wang et al. (2024) used a large dataset of around one million chess positions named “Move on strAtegy and Tactics datasEt” (MATE) to compare selected moves with commercial models. They concluded that “language explanations can enhance the reasoning capability of large language models”.

Automated Case Elicitation (ACE) enables Case-Based Reasoning (CBR). Knowledge can be acquired automatically through environmental interaction and real-time exploration. Learning and being able to match the computer chess programme Stockfish indicated it should be able to impact other areas, such as gaming and other problem-solving domains (Weitl-Harms et al., 2024).

Reflection

A study of the reflective thinking skills of 200 children learning chess in Anambra State, Nigeria, adopted a non-randomised, pretest-posttest, quasi-experimental design and ran for nine weeks (Ezennaka & Unachukwu, 2023a). Multi-stage sampling was adopted. The Verbal Cognitive Reflection Test (CRT-V) was used for data collection. The study's results indicated that learning chess significantly positively affected students' reflective thinking skills.

Spatial Ability/Concept/Orientation

Stegariu and Iacob (2022a) conducted a Romanian study with fourth-grade students. The study involved a chess group of 16 and a non-chess control group of 16. The instruments used were the Bender-Santucci Test (spatial orientation) and the Similarities Test (logical thinking). The chess group scored better in both tests, which correlated statistically. A correlation between analytical thinking and spatial orientation was also recorded.

The same researchers completed a second study (Stegariu & Iacob, 2022b) exploring the relationship between attentional abilities and spatial orientation. The Bender-Santucci test (spatial orientation), the Kraepelin test and the Toulouse-Pieron test (attentional abilities) were used to measure the relationship. The study involved 20 third-grade students (10 chess and 10 control). There was a statistically correlated result favouring the chess group, while spatial orientation and attentional abilities were moderately correlated.

Theory of Mind

A Turkish study involving 41 children who received chess instruction and 46 children who did not (both groups' average age was 68 months) resulted in statistically significant results in favour of the chess group for both creative thinking and theory of mind tests (Sigirtmac, 2016). The researchers acknowledged that studies that include pretests and posttests and larger sample sizes would be helpful.

A Texas, USA study by Trevino (2019) utilised an online survey to examine the relationship between Theory of Mind (TOM) and chess playing among two groups: 31 adult United States Chess Federation (USCF) rated members and 202 non=USCF rated members on TOM scales. There were no significant differences found. However, results indicated that empathic concern, false belief understanding and perspective-taking predicted players' reports of chess playing frequency. Future research could focus on teaching empathy. Perhaps chess could be a practical means of facilitating the development of TOM for prosocial interactions – for example, for those with autism.

Verbal Reasoning

A study in India (Joseph et al., 2018) involving 70 children (male 43, female 27, average age 11) who underwent one year of systematic chess training and 81 children (male 52, female 29, average age also 11) who played sports like hockey, football and cricket examined the effect of one year of systematic chess training on children's verbal reasoning. The male and female children were from Grades 3-9 in two private and two government schools. A pretest-posttest design was adopted, and verbal reasoning was measured using the Binet–Kamat Test of Intelligence (BKT). The chess group recorded significant gains in verbal reasoning compared to the control group, measured by Analysis of Covariance (ANCOVA), and improved IQ, measured by a t-test. The researchers claimed the findings related to verbal reasoning were important because they were previously unresearched.

Eberhard (2003) conducted a study in Texas that involved 60 chess students (of whom 41 were economically disadvantaged) and 93 in the control group that did keyboarding (55 were economically disadvantaged). Tests involved were the Cognitive Abilities Test (CogAT), the Texas Assessment of Academic Skills (TAAS) and the Naglieri Non-Verbal Ability Test (NNAT). After 13 weeks, the chess group that was not economically disadvantaged showed a significant improvement in verbal reasoning.

Visualisation

Fine (1965) believed that visualisation is one of many learned skills that lead to chess skills. According to Schneck (2005), those involved in education and chess learn better from visual than from auditory information. Basson (2015) observed that expert chess players regularly apply sports psychology in chess, such as by constructing and manipulating imagery, field searches, mental modelling and "chess-specific visual iterative analyses" (p. 44). She noted that several researchers have proposed that visualisation is an ingredient of chess expertise (Campitelli & Gobet, 2005; Frydman & Lynn, 1992, p. 235; Howard, 1999, 2005; Saariluoma, 1992). Although Basson discussed visualisation at length in her thesis, she did not use a measuring instrument for visualisation in the quantitative section.

Visuospatial Skills

Waters et al. (2002) found no evidence of a correlation between the chess ability of 36 adult chess players (average age 28) and their visuospatial skills. In his thesis, Noir (2002) argued that thinking several moves ahead is done mentally; “the visual system for processing spatial coordinates and spatial dynamic relationships thus becomes very efficient”. He hypothesised that, since the chunking score in his study related to practice, “chess practice has entered their capacity for visuospatial perceptual processing”. Noir discussed these issues at length and concluded by noting that his experimental protocols attest to the most important skills for learning chess in the context of the school curriculum: memorisation strategy, calculation and combinations, mental imagery and visuospatial processing.

An analysis of global graph measures indicated stronger cognitive results for chess players than controls for visuospatial abilities (Gonzalez-Burgos et al., 2024).

Based on temporal and spatial analysis, experts displayed significantly better visuocognitive performance. They showed significantly higher fixation on empty squares and key areas of the board. It was demonstrated that experts benefit from their stored checkmating pattern chunks (Küchelmann et al., 2024).

A study by Smith et al. (2021) involved 14 advanced chess players and 15 beginners using chess boards and pieces of differing shapes and sizes. Varying results were found for familiar and unfamiliar stimuli.

Working Memory

A study by Joseph et al. (2020) funded by the Indian government noted that:

> *Working memory is the ability to actively maintain information in conscious awareness, carry out cognitive operations, and produce an outcome. Working memory holds a small amount of information in the mind and is used in executing cognitive tasks, in contrast to long-term memory, which is extensive.*

This study involved two years of chess training for 88 children from Grades 3-9 in the chess group, while 90 in the control group undertook other sports or extra-curricular activities. At the second-year assessment, the group sizes had reduced to 80 in the chess group and 77 in the control. Two Wechsler Intelligence Scale for Children—Fourth Edition (WISC-IV) INDIA subtests were used to measure working memory. Significant gains in working memory for the chess group over the control group were recorded, indicating a relationship between chess training and working memory.

An experimental pretest-posttest study conducted in Ahvaz City, Iran by Atashafrouz (2019) involved 20 Grade 10 male students in the chess group and 20 in the control group, who were enrolled using a multi-stage random method to investigate the relationship between chess and problem-solving, working memory and concentration. Measurement instruments were Cassidy and Lang's problem-solving style questionnaire (PSSG), Cornoldi's working memory test (CWMT), and Weinstein and Palmer's learning and study strategies inventory (LASSI). The chess group received 15 sessions of chess training over four months, and the control group did not. Results indicated a significant improvement in working memory and concentration, but not in problem-solving, for the chess group over the control group.

A meta-analysis by Sala and Gobet (2017c) evaluated the effects of working memory training, indicating small to moderate effects. However, effect sizes and quality of experimental design were inversely related. The researchers concluded: "The meta-analytic reviews presented in this article strongly suggest that the optimism about the far-transfer effects of cognitive training is not justified, at least with typically developing children and adolescents".

2.4 Key Thinking Skills

Abstract Thinking

Celone (2001) conducted research with 7- to 14-year-old chess students in Connecticut, USA using the TONI-3 test of nonverbal intelligence, claiming positive results for abstract thinking skills. Horgan and Morgan (1986) undertook a study involving 94 strong junior players. They contended that "data from the memory and reconstruction tasks strongly support the general hypothesis that abstract, semantically organised pre-stored schema (PSS) is an important component of chess cognition”.

A small study by Laws (2014) of five secondary school students with varying chess abilities involving interviews, blindfold chess, simultaneous play and notation allowed him to “extract meaning and code schemata into a holistic understanding of the phenomenon of abstract cognition within the context of Piaget’s Formal Operations Stage”. While these studies are inconclusive, they offer evidence that chess may be helpful for players’ abstract thinking skills and thus invite further research.

Algorithmic Thinking

Karapetyan (2021) surmises that chess may help children develop algorithmic and programming skills. The game’s nature, which emphasises planning, evaluation and decision-making, mirrors the iterative process of formulating and executing algorithms to achieve desired outcomes. The structured environment of chess may provide children with an effective means to improve their algorithmic thinking skills. Further, these are “an effective way to develop the preconditions for children’s educational activities in the learning process”.

Analogical Thinking

Of the 87 six-year-olds in a study conducted in Ankara, Turkey by Gunes and Tugrul (2016), a significant majority made an analogy between chess playing and life skills. This analogy led the authors to believe that the children held positive emotions about chess, affecting their game choices.

An experiment by Cauzinille-Marmeche and Didierjean (1998) involving 44 young adult novice chess players lasted approximately one hour. The experiment suggested different ways of problem solving by analogy. An example was the use of abstract schema and/or adaptation of a source case. Various measures enabled the researchers ‘to identify different forms of source example processing, storage, and retrieval for solving new isomorphic problems’.

These experimental results thus support the hypothesis that solving chess problems for adults could be linked to their previous similar experiences not directly associated with chess. The authors of both studies highlight valuable insights into broader connections with analogical thinking for adults and children.

Analytical Thinking

Stegariu and Iacob (2020) conducted a study involving 16-year-old students who practised chess. They were randomly divided into two groups: an experimental group that received chess instruction for a term; and a “do nothing” control group. The researchers noted that the chess children found it difficult to accept that they had made a wrong move in the first test, but this problem was resolved in the second test. The chess group registered a substantially better time on the final IQ puzzle test than the first, leading the researchers to believe that learning to play chess may help children develop their analytical thinking abilities. They concluded that this supports the case for introducing chess into the school curriculum.

Anticipation

In his book *The Psychology of Chess*, Fernand Gobet (2018, p. 11) introduced an idea, initially proposed by de Groot (1978), that chess masters use anticipatory schemas. Ferrari et al. (2006, 2008) found that expert chess players’ knowledge is structured by goal-oriented processes such as anticipation and their perception appears to be tied to visual and strategic information.

Argumentation

Peran (2019) used chess positions and moves to create “didactic metaphors” and “dynamic learning environments” to demonstrate the importance of correct legal argumentation.

Categorising

Noir (2002) proposed that a categorisation strategy can be applied to chunking and transfer theories because of the similarity of knowledge structures. Grouping by semantic category is considered relevant for memorising, for example, a list of words rather than by traditional means. “The distinction by functional and structural properties is more efficient, but it also refers to a dichotomy between visual and verbal modalities” (p.198).

Conceptual Thinking

Sigirtmac (2012) conducted a study in Turkey that involved 50 six-year-old children who took a chess course and a control group of 50 who did not. The researcher developed and tested concepts in chess instruction using a chess board. Based on the children’s scores from the concept test, the Mann-Whitney U test (a nonparametric statistical test of the null hypothesis) revealed a statistically meaningful difference in all concepts in favour of the children who took chess courses. There were no meaningful gender differences for any of the concepts.

Mechner (2010) wrote a definitive compendium on blindfold chess. Conceptual thinking was a constant theme in the book, and he regarded concepts as chunks, templates or patterns. He believed the topics covered had implications for “conceptual and research issues in behaviour analysis, psychology, neuroscience, performance learning, training, and education”.

Contextual Factors

Many contextual issues expound the educational benefits of children learning to play chess, which are essential to the success or otherwise of chess learning programmes. Mirakhanyan et al. (2017) identify some factors that impact chess programmes to some extent. These include parents’ educational level, passionate teachers and supportive family environments. Romanova et al. (2018) consider skill acquisition and age-appropriate instruction important. Cleveland (1907) warn that too much competition might discourage some students.

Creative Thinking

A study by Sigirtmac (2016) conducted in Turkey involved 41 children who received chess training and 46 children who did not (average age 5.5 years). The students who received chess coaching scored significantly higher in tests for creative thinking and theory of mind. The quantitative studies by Joseph et al. (2017, 2021) produced similar results.

Hichem et al. (2023) used the Hermann Brain Dominance instrument. They concluded that learning chess can assist creative and logical thinking abilities. The test also has implications for identifying the most used area of the brain. The findings support Romanova et al. (2018) in that learning to play chess might change one's thinking compass. Hichem et al. (2023) also suggest that chess may have practical value in multiple domains.

Critical Thinking

A 10-week study conducted by Berkley (2012) indicated that chess instruction did not improve the critical thinking ability of chess students, even though the students believed that it did. By contrast, a meta-analysis of the literature on the relationship between chess instruction and critical thinking skills conducted by Gates (2015) showed clear findings of a connection with children learning chess. It indicated improved critical thinking scores in a relatively short timeframe.

A study by Brusamolin and Pedroni (2024) found that chess offers a "holistic approach to education" by fostering problem-solving and critical thinking, enriching social and emotional growth, and contributing to the overall learning experience.

Researchers from Armenia argue that, for critical thinking to be learnt from chess involvement, strategies such as group activities, debates, working in pairs and the exchange of ideas need to be invoked (Khachatryan et al., 2024).

Dialogic Thinking

In a study involving researchers from Spain, India and the UK, Sundaramadhavan et al. (2021) endeavoured to understand what works for children in the classroom to address inclusion issues through teaching chess. Four facilitator groups examined different modalities: a) those with ADHD; b) gender; c) teacherless self-organised learning; and d) formal chess in the school programme. Examples of dialogic thinking shared by facilitators in these environments included the exploration of "desires, necessities, curiosities and power".

Divergent Thinking

Two studies, Joseph et al. (2021) from India and Sigirtmac (2016) from Turkey, examined the relationship between children learning to play chess and their creative and divergent thinking skills. Divergent thinking involves looking at a problem and generating many ideas to address it, whereas creative thinking involves selecting valuable ideas that work in practice.

The Indian Wallach-Kogan Creativity Test (WKCT) used in the Joseph et al. (2021) study, which involved 99 children aged 6-16 and focused on divergent thinking, showed positive results. The Sigirtmac (2016) study involved 87 children with an average age of 5.5 and used the Torrance Test of Creative Thinking (TTCT). This study also involved divergent thinking and showed positive results.

Intellectual Ability

A study by Glukhova (2017) detailed the “Chess for Overall Development” programme in Russia. It aimed to “increase the development of intellectual processes in children learning to play chess”. Between 2004 and 2017, approximately 870 Grades 1-9 students participated in a longitudinal study. The subjects outstripped the two comparison groups: a group that studied chess using the “Chess Universal” programme of Igor Sukhin; and a group that did not study chess. “Their visual and aural memory improved, and they began to cope better with tasks for non-verbal thinking. They became more attentive, performed, and were more able to plan their actions. No negative dynamics for any indicator were found’.

Zaretsky et al. (2023) provided a progress report on the continuing “Chess for Overall Development” programme. They included examples of their work, which included disabled children. Their current project is to transfer the experience to other schools around Russia.

Stegariu et al. (2019) conducted a Romanian study involving 67 primary school students using Ravens Standard Progressive Matrices (RSPM) to examine the effect of chess learning on their intellectual development. Results indicated that the advanced group scored significantly better than the beginner and “no chess” control groups.

Mărăcine and Mihăilescu (2023) from Romania conducted a study in 2022-2023, in which the chess group involving 47 11-12-year-olds studied the optional subject “Education through Chess” through the 2022-2023 school year, with a control group that studied another optional subject. The tests were the Mathematical Calculation test, the Mathematical Reasoning test, the Text Comprehension test and the Analytical Reasoning test. There were significant differences in favour of the chess group in intellectual/mental development and thinking functions.

Intuition

Many papers have examined the relationship between chess players and intuition, including Linhares (2005), Gobet and Chassy (2009), Buhren and Frank (2012), Gobet (2017) and Smith (2021). Recently, Chassy et al. (2023) conducted a quantitative study using 63 master-level chess players to test the theory that expert intuition requires a holistic understanding. The masters were given short presentation times and asked to evaluate chess positions that required an understanding of the position. The researchers claimed that “the results support the central role of holistic intuition in expertise”.

IQ

A Romanian study by Stegariu et al. (2023) involved two third-grade classes totalling 67 students (31 male, 36 female). They received 12 months of chess instruction once a week. Ravens Progressive Matrices for IQ and the Bender-Santucci test for Spatial Orientation were used for before-and-after testing. The tests revealed a significant “before-and-after” improvement and a high correlation between IQ and Spatial Orientation for both groups. The students improved from average to superior IQ.

Grabner (2014) argues IQ is an important ingredient when starting chess, but dedicated practice soon becomes the most important factor in chess excellence. Based upon the author’s personal experience with hundreds of junior chess players over 30 years, Grabner’s contention is supported.

Logical Thinking

Belova (2018) highlighted the importance of preparing exercises that prioritise developmental requirements and logical reasoning skills in the early years. Masharipova and Matyusupov (2023) trialled experimental technology based on the teaching environment to develop the logical thinking of primary school students. A study in Uzbekistan (Quchqorivich, 2022) significantly based an elementary school curriculum on developing students' logical thinking skills through learning chess.

Stegariu and Iacob (2022a) conducted a study involving 32 fourth-grade students in Romania. The experimental group scored better in a logical thinking test, which correlated statistically. The researchers concluded that chess instruction improves primary school students' development.

Original Thinking

Original thinking is a process that produces innovation and invention, perhaps something novel or unexpected. Eighty-seven children, with an average age of 5.5 years, participated in a chess study in Turkey for two hours a week over seven months (Sigirtmac, 2016). The Theory of Mind (TOM) and Torrance Test of Creative Thinking (TTCT) tests found a positive, statistically significant relationship for original thinking.

Patience

A randomised study in Bangladesh involved 569 Grade Five students (treatment 281, control 288), predominantly from an underprivileged, low socio-economic background (Islam et al., 2021). It involved 30 hours of chess training over 12 days in three weeks. No improvement was recorded in tests for children's patience. Rimban (2023) argues that chess induces patience without providing evidence. Like many aspects of chess, if learning chess does help with patience, this will be shown only in a longitudinal study.

Rational Thinking

Fourteen randomly selected adolescents aged 12-18 participated in a study in Algeria that examined the effects of learning chess on thinking patterns (Hichem et al., 2023). The Hermann Brain Dominance Instrument Test (HBDI), which identifies thinking patterns, was used. The researchers found that "learning and practising chess mental activity can significantly impact an individual's thinking compass" and improve rational and creative thinking scores. It supports Romanova et al. (2018) in that one's thinking compass can be changed through learning chess.

A study from Cluj-Napoca, Romania (Varga & Marschalko, 2024) involved 90 Romanian and Hungarian serious chess players (48 male, 42 female) with an average age of 32. The researchers concluded that practice was an important factor in developing a-level competence, but that rational thinking was crucial.

Science

A study conducted in India by Joseph et al. (2016), involving 100 sixth grade students, showed significant improvements in their science scores. Uskokovic (2023) from the USA wrote an essay in which he urged educators to complement science classes with chess lessons, and recommended that chess become an integral part of education in schools and universities. However, a randomised study by Jerrim et al. (2018) in England involving 4009 students from multiple schools showed no positive findings in science scores.

An Australian study (Thompson, 2003) involved 508 Grades 6-12 students, including 64 regular tournament players from an independent school in Adelaide, Australia:

> *Data from the Australian Schools Science Competition were Rasch scaled and placed on a single scale for all the grades. Multilevel analysis using hierarchical linear modelling was employed to test the effects of the hypothesised variables. No significant effect of chess playing on the science scores was found.*

Uskokovic, 2024, from California, USA, commences, "Lying halfway between science and art, chess presents an excellent model for instructing the new generation of scientists about the merits of artistic senses for the exhibitions of scientific creativity". He then uses chess games and world champions since the mid-19th century to demonstrate his claim.

Strategic Thinking

A survey of 62 teachers who taught chess throughout an academic year (2018) in several school districts in a Southern state of the USA indicated they were enthusiastic about chess instruction and held mainly positive perceptions regarding student benefits (Chitiyo et al., 2021). Strategic thinking was ranked second behind problem-solving in a list of perceived benefits.

A study by Meloni and Fanari (2021), who regard chess as a “model environment for research in problem-solving and expertise”, showed no effect on metacognitive scores between the chess and the control groups.

Advanced players tend to prefer longer, neutral, strategic openings, while lower-rated players prefer sharper, tactical openings (Salmi, 2024).

Subjective Thinking

Can humans distinguish whether they are playing chess against a human or a computer? Eisma et al. (2024) conducted a study that substantially tested the relationship between human and computer moves, using the Turing test (a test of a machine’s ability to exhibit intelligent behaviour). Most participants correctly identified the computer programme Stockfish, whereas another programme named Maia was regularly misidentified as a human.

Thinking Patterns

An Algerian study by Hichem et al. (2023), utilising a descriptive approach and Hermann's brain theory, investigated the relationship between 14 randomly chosen adolescents learning chess and their thinking patterns. There were mixed results regarding changes to the thinking compass and thinking values of the sample relating to emotional, executive, rational and creative thinking. The authors concluded that learning and practising chess through their mental activity can significantly impact an individual’s thinking compass.

Bilalić et al. (2010) analysed eye movements. They found that those chess players considered to be experts immediately concentrated on critical aspects, while novices also did this but wasted time on irrelevant ones. Expertise, controls, dependant measures, and object and pattern recognition were identified as essential ingredients in expert visual cognition.

A study funded by the Indian government by Joseph et al. (2017) used the Wallach-Kogan Creativity Test (Indian adaptation), involving 63 students (31 chess, 32 control) to examine the effects of one year of chess training. The results showed that only the chess group had significant gains in the Line Drawing and Pattern Meaning subtests.

2.5 Physical, Psychological and Emotional Wellbeing

Acceptance and Commitment Theory

Acceptance and Commitment Theory (ACT) is a mindfulness therapy that assists those with mental conditions such as stress, anxiety, depression, substance abuse and phobias with staying focused in the moment and being nonjudgemental about their thoughts and feelings. A study by Ruiz and Luciano (2012) involving five international standard chess players and conducting a four-hour ACT intervention "reduced counter-productive reactions during chess competitions" and improved their performance.

Ruiz et al. (2023) conducted a small-scale Spanish/Columbian case study, with five ACT interventions and some follow-ups, on two elite chess players, matched with two similar chess players with similar symptoms who did not receive the intervention. The control pair showed no improvement in chess performance, but the elite chess pair showed significant improvement as measured by their international chess rating (ELO) performance.

A study conducted in Karaj, Iran in 2019 by Teimoory (2022) involved three groups of 15 professional adolescent chess players selected by purposeful sampling and randomly assigned as follows: 1. Mindfulness-Based Stress Reduction (MBCR); 2. Acceptance and Commitment Therapy (ACT) (1 and 2 each received eight sessions); and 3. a "no treatment" group. The Beck Anxiety Inventory-II (1996) (a self-report measure of anxiety) and the London Computer-based Tower Test (Shallice, 1982) were the instruments used for data gathering. There were significant results for both MBCR and ACT, impacting both anxiety and executive function for chess players. It was suggested that sports psychologists use these methods.

Agreeableness

A study by Bilalić et al. (2007) involving 269 students, 219 of whom participated in regular school chess programmes, and two-thirds of whom were boys, with an average age of 10.1, from four schools in Oxfordshire, UK, found that those with higher agreeableness scores appear less likely to take chess seriously. The study found that girls scored higher on agreeableness, potentially a reason more boys maintain an interest in chess. The instrument used was the Big Five model (BFQ-C) (Barbaranelli et al., 2003), which measures personality profiles.

Autism Spectrum Disorder (ASD) and ADHD

The relationship between learning chess and the concentration levels of 14 students aged 11-13 with ADHD was examined in a study by ElDaou and El-Shamieh (2015). The students were selected from two schools in Saida, Lebanon, with chess sessions twice weekly. Results using the Conner's Teachers Rating Scale showed that students took longer before exhibiting unacceptable behaviours. The authors stated, "It is important for students to learn chess as it trains them to stay longer on task, control their actions and maintain focus".

Before students participated in an 11-week chess programme in Madrid, Spain, parents contributed to a study of 44 children aged 6-17 with ADHD (Blasco-Fontecilla et al., 2016) by completing the Swanson, Nolan and Pelham Scale (SNAP-IV) for parents, a 90-question self-report inventory designed to measure ADHD and oppositional defiant disorder (ODD) symptoms in children and young adults. Also, the Abbreviated Conner's Rating Scales for parents (CPRS-HI) is a 10-item scale used by parents to report on a child's hyperactivity and impulsivity. Results showed decreased severity of ADHD and a correlation between IQ and SNAP-IV improvement ($p<.05$).

A single-case study in Canada (Nechio, 2016) examined the perceptions of an adult female chess player with ADHD who undertook a 10-week programme of solving chess puzzles. The chess players undertook semi-structured interviews, the Barkley Adult ADHD Rating Scale (BAARS-IV) and the Barkley Deficit in Executive Function Scale (BDEFS) tests before and after the chess programme, and they were asked open-ended questions at the end. Based on the participants' perceptions, results indicated improved working memory and other executive functions and reduced ADHD symptoms, particularly inattentiveness.

A study from New York, USA (Bornstein & Cunningham, 2023) involved six students diagnosed with mild to high-functioning ASD. Some encouraging results were shown for their working memory and focused attention scores. The researcher concluded that further studies should be conducted regarding the limitations addressed – e.g., small sample size, gender and so on.

Body Schema

Horgan (1987) describes schemas as knowledge representations: “Rapid testing and retesting of schemas may accelerate development”. Constant revision may be more critical in keeping schemas flexible. The fact that chess players keep scoresheet records of their games and then revise their games with an opponent, their chess coach or even their computer programme is an excellent way of keeping their schemas flexible. Horgan asserts that, “because children’s schemas are naturally fluid and open to moderation, overall, this may help children learn faster”.

Sixty-seven third-grade students in Romania undertook pre- and posttests: Ravens (for IQ) and Goodenough (for body schema). A linear relationship between IQ and body schema was indicated, meaning “body schema can be educated through chess lessons”, leading to improved psychomotor development (Stegariu et al., 2022).

Consonance and Dissonance

A study by Mirzakhanyan et al. (2019) in Armenia examined a randomly chosen group of Grades 2-4 chess players. It looked at consonance and dissonance from the school psychologist’s perspective. Two tests were used. Eysenck’s personality psychometric test (Eysenck & Wilson, 2000) measured emotional stability/instability, and the “Big 5” test (Goldberg, 1990) measured the degree of readiness for gaining new experiences. Consonance was present in those children looking for new experiences during the game, and these children appeared well-behaved towards their opponents. The group of children displaying dissonance and argumentation could be regarded as “extraversion – emotional instability”. More than with introverts, these children required the support of the school psychologist.

Mental Imagery

Noir (2002) observes that, because chess players are not allowed by the game’s rules to touch the pieces before making a move, mental imagery and chess playing are utilised as a research medium. He asks, “Does the practice of visual[ly] scanning the chessboard and processing potential movement by mental imagery develop a skill whose benefits would be extended to any task of processing spatial relations and visual stimuli?" Noir compares chess with the ability of video games to process visual stimuli. The "mental imagery necessary for reasoning" and "spatial relations at the perceptual level" are typical in video games and chess.

CHREST (*Chunk Hierarchy and REtrieval Structures)* is a cognitive architecture that models human perception, learning, memory and problem-solving. It has been successfully applied in some areas, including the psychology of expert behaviour and the presence of a perception-learning cycle, and may help develop artificial intelligence (Gobet & Simon, 2000).

Waters and Gobet (2008) conducted a CHREST study of 36 chess players ranging from amateurs to grandmasters. Players were asked to recall briefly positions ranging from the game (standard) to randomised positions placed on squares' intersection, edge or centre (standard). All players recorded much poorer recalls for intersection positions than for standard positions. The authors claim that the article sheds light on mental imagery and chunking and establishes the "plausibility of CHREST's mechanisms for explaining mental imagery, at least in chess".

Mental Wellbeing

A Russian study by Makhova (2017) used the SF-36 Health Status Survey to examine the self-assessment of the quality of life of students with disabilities and special medical groups who joined chess classes. Students believed chess positively impacted their quality of life, helped them to be more resistant to psycho-emotional and physical stress, effectively overcame a "vicious circle of communication", and helped them acquire new knowledge, skills and information.

A Spanish study (Fuentes-Garcia et al., 2020) involving 450 chess players of all standards in countries where isolation was mandatory aimed to "analyse the effect of the coronavirus disease of 2019 (COVID-19) confinement on behavioural, psychological, and training patterns of chess players based on their gender, level of education, and level of chess played".

The results were analysed in detail, and the following observations were offered: players reduced exercise and increased chess practice; perception of alarm is more significant in the lower level of play; and neuroticism, psychological inflexibility and extraversion are higher in the higher level of play. Higher levels of personal concern and anxiety seem to be related to higher academic levels as well as to lower psychological inflexibility levels.

A case study involved the treatment protocol for a patient requiring brain surgery to remove a tumour who requested to retain the ability to play chess. This request was achieved using a combination of functional Magnetic Resonance Imaging (fMRI) and Electrical Stimulation Mapping (ESM), and a plausible protocol for treatment in similar cases was developed (Capero-Escribano et al., 2024).

If the results of a study by Cheragh-Birjandi et al. (2024) are replicated, consuming omega-3 and playing chess can improve elderly people’s cognitive performance, learning, memory, physical condition and neural growth.

Salivary cortisol is a hormone found in saliva that can be used to measure the body’s stress response. This study involved 15 serious girl chess players who participated in a chess competition over five days. Salivary cortisol and mood were measured throughout the event. Winners had considerably higher cortisol levels than losers. Mode disturbance, anger and tension were considerably higher following critical rounds. It was found that participating in this competition resulted in increased salivary cortisol and negative alterations in mood (Dovom et al., 2024).

A female chess grandmaster was selected to participate in a case study. Neurofeedback and biofeedback training combined with chess training resulted in sustained improvements in chess and non-chess tasks a week after the intervention. Annual monitoring highlighted long-term benefits (Fuentes Garcia & Villafaina, 2024).

Lillo-Crespo et al. (2019) conducted a scoping review involving 21 papers. They found that the use of chess for the treatment or prevention of dementia was inconclusive.

A study from Uzbekistan (Lutfilloevna & Kumar, 2024) examines adverse medical conditions arising from overtraining in young chess players. For example, postural disorders arising from overtraining can result in spinal disorders. Mental and emotional stress affects the psychophysiological conditions of young chess players, which can lead to conditions such as myocardial infarction, hypertension and stroke. The researchers argue that monitoring the medical condition of elite young chess players should be mandatory.

Mărăcine and Mihăilescu (2024) questioned whether chess practice aids the psychosocial development of young chess players. This controlled study from Gorj County, Bucharest, Romania, involving 47 fifth-grade students (22 girls, 25 boys), studied students' attitudes and behaviours, psychosocial behaviour and school discipline. The results indicated a significant improvement in the three disciplines for the chess group, particularly in psychosocial behaviour.

A study from Tashkent Pediatric Medical Institute, Uzbekistan (Mukhamejhanova & Sadikov, 2024) involved 190 serious chess players aged 6-11 and 60 secondary school students, with an average age of 9.8 years, who were not involved in chess. Electroencephalogram (EEG) examinations (measuring electrical activity of the brain) were used to study mental stress. Chess players demonstrated a "consistently higher level of cortex activation" than the control group. Also, increased mental and psycho-emotional stress and participation in competition resulted in "tension in adaptation mechanisms".

Sari-Sarraf et al. (2024) investigated the effect of beta and gamma waves on central and frontal brain regions in 26 18-year-old chess players. They found that, by modulating beta and gamma waves, chess training can improve the skill performance of the chess group.

Mindfulness

Ashgari et al. (2023) conducted a quasi-experimental study involving 30 adolescent chess girls in Azerbaijan to examine the relationship between mindfulness exercises and the Theory of Mind. The experimental group underwent mindfulness exercises, and the control group did not. Both groups completed Happé Mind Theory questionnaires before and after the study. Results showed that the mindfulness group had a positive and significant result and improved cognitive power.

A Spanish cross-sectional study involving 123 chess players using self-administered online questionnaires was conducted by Balagué I Canadell et al. (2023) to study the relationship between mindfulness and self-compassion and chess players' mental preparation. Structural equation modelling (SEM) indicated positive relationships between mindfulness and self-compassion as well as depression-anxiety-stress construct and sleep difficulties. Also, a significant relationship was noted between the length of time practising mindfulness and depression, depression-anxiety-stress construct, awareness and self-compassion.

Motivation

A study by Holland by de Bruin et al. (2007b) used a questionnaire to examine the relationship between motivation and deliberate practice among elite adolescent chess players. They found that achievement and chess-specific motivation were critical to undertaking significant deliberate practice.

A randomised study (Kazemi et al., 2012) involved 180 Iranian male students from the 5th, 8th and 9th grades separated into two groups: children who had studied chess for six months, and those who had not. The chess group scored 16.9% higher in problem-solving than the control group. An analysis of the Mathematics Motivated Strategies for Learning (MMSLQ) questionnaire indicated that the level of chess training can influence high-level thinking skills and motivational beliefs.

Noir (2002) from France noted that, “to maintain a high degree of motivation, it is necessary to find the exploration heuristics that are the basis of the in-depth calculation of the current moves of a game”.

Lower ability chess players in a Lebanese chess tournament were offered high quality advice to see if it affected their performance (Bouacida et al., 2024). However, much of the advice was wasted because subjects, particularly those with lower ability, tended to keep their initial evaluation.

A study from Armenia (Melkonyan et al., 2024) concluded that “Chess in Project Based Learning can provide a smoother transition from primary school to secondary school and promote motivation in the educational process because project-based works motivate teachers and learners by their nature and content”.

A study by Charness et al. (2004) examined the motivations for chess players to engage in many hours of deliberate practice to achieve a high level of expertise.

A study from the Philippines (De Lemios et al., 2025) found that educational games, including chess, can significantly enhance learning motivation and effectiveness. The study involved 24 Grades 4-6 students from Tabugon Elementary School and found increased positivity about and interest in solving maths problems.

Fifty Grade 8 students (19 male, 31 female) from Libertad National High School, Tandag City, Philippines participated in a study involving chess-based instructional materials (Petallo & Berry, 2024). Students' posttest scores significantly improved.

Purposefulness

A Hungarian study by Medvegy et al. (2022) utilised a questionnaire to measure the resilience of 396 participants, who were divided into three groups: tournament chess players; hobby chess players; and non-players. Amongst other attributes, purposefulness was rated highly by chess players. They appeared more focused and met their challenges efficiently. "They seek the reasons for their failures, which helps them to improve their skills."

Relative Age Effects

Data from all registered Belgian chess players from 2009-2013 were analysed in a study conducted by Helsen et al. (2016). There were relative age effects: the likelihood of participation was significantly higher for players born in the first quartile, and significantly lower for those born in the last quarter. This finding was particularly so for the under eight and under 10 age groups. Also, those children born in the first few months of the relevant year were significantly more often in the top 10 players in each age group of the Belgian Youth Champs in 2013. Interestingly, the disappearance of relative age effects in older age categories could not be explained.

Age performance relationship (APR) tasks were analysed using data from results and ELO ratings (players' performance) from international chess tournaments (1970-2021), with positive results (Kalwij & De Jaegher, 2023).

Resilience

The study by Medvegy et al. (2022), cited previously, mainly focused on resilience. The questionnaire results indicated that chess players react better to crises, stick to their goals, work diligently through challenges, make difficult decisions under pressure and lead healthier lifestyles. The authors claimed that the results showed that psychological factors and physical activity from an early age help improve resilience and adaptability in physical sports.

Risk Aversion

A randomised study by Islam et al. (2021) involving 569 primary school students (treatment 281, control 288) conducted in Bangladesh by researchers attached to an Australian university found that “chess training reduces the treatment group’s level of risk aversion almost a year after the intervention ended”. This finding was less conclusive once the researchers accounted for multiple hypothesis.

The study also found improved maths scores, reduced time inconsistency and non-monotonic time preferences, although these results were less conclusive when using multiple hypothesis testing. Interestingly, 90% of students were still practising and competing in chess nine months after the intervention.

Carow and Witzig (2024) investigated the effects of time pressure and strategic risk-taking among professional chess players and found that it led players to choose more risk-averse moves. There was also correlational evidence that players chose more risk-averse moves after mistakes in adverse positions.

Self-Efficacy

Self-efficacy has been the subject of research in physical sports, but not non-physical like chess (Olivo & Barbaranelli, 2023). The researchers from Italy developed and validated a 63-item “Chess Self-Efficacy Scale” (CSS). The scale could be used in training by coaches and players to identify areas for improvement and to achieve ambitious goals. Apart from performance, managing emotions, stress and anxiety is also important. A chess instructor may “plan an intervention to develop specific domains, more general intermediate areas, or a general sense of chess mastery”. CSS has captured chess players’ ability to handle negative emotions, prepare strategies, find practical solutions and counter negativity and despondency.

Self-Esteem

A study in China lasting nine months in 2016/2017 involved 31 Grades Three/Four students who were taught chess and a control group of 90 from the same grades who were not (Jianguo et al., 2019). The chess group had also played chess in Grades One and Two. One hundred and twenty-one questionnaires were distributed before training and collected immediately afterwards. Results were analysed using the General Self-Efficacy Scale (GSES), the Self-esteem Scale

(SES) and the Social Anxiety Scale for Children (SASC), and concluded that the chess group showed significantly positive results for all three tests over the control group.

Socio-Emotional

Aciego et al. (2012) undertook a Spanish study with a quasi-experimental design involving 170 children aged 6-16 years who undertook chess as an extra-curricular activity, and a control group of 60 that did basketball or soccer over a school year. Intellectual and socio-affective competence was measured by a self-report test (TAMAI), an IQ test (WISC-R) and a hetero-report questionnaire that were administered at the beginning and end of the school year. Positive results were found in the chess group but not in the control group for cognitive abilities such as attention, resistance to distraction, perceptive organisation, speed, planning, foresight, coping, socio-affective development and problem-solving.

Four years later, the same research team used a quasi-experimental design with Chess Group 1 (n=110) focusing on comprehensive training, Chess Group 2 (n=60) on tactical training and Control Group 3 (n=60) on basketball and football (Aciego et al., 2016). Both chess groups scored significantly superior results in cognitive and socio-personal skills compared to the basketball/football group.

Social Reasoning

Nine chess players in California, USA received semi-structured interviews to understand the role of social cognition in strategy formation (Smith, 2021). The relationship between “cognitive processes that reference social reasoning traits” and “interpersonal strategy decision-making” was addressed. Cognitive empathy, memory, spatial calculations and intuition were essential in chess strategy.

Stress

A study in Tashkent, Uzbekistan (Mukhamedjanova, 2020) involving a study group of 87 experienced chess players with an average age of 10.1 years and a control group of 85 children with an average age of 9.8 years who did not play chess examined stress factors. In the context of introducing new strategies and standards of education in Uzbekistan and maintaining good health amongst children during one of the most stressful periods of their young lives, this research measured participants' heart rhythms as an indicator of stress under mental loads. Results indicated differing stress responses between girls and boys, indicating more research is justified.

A study involving 12 serious junior chess players from Banyuwangi, Indonesia aged 15-18 (Purnomo et al., 2024) measured stress levels. Players were measured with mild stress levels for classic time controls (90-120 mins a side) and fast (10-25 mins a side) and normal stress levels for lightning (3-5 minutes a side).

A six-month intervention involving 45 students from three Romanian localities used chess training to measure improvements in their chess (three variables), stress and self-esteem (Stegariu et al., 2025). There were statistically significant improvements in each of the five variables. The researchers consider the results "support the integration of chess and wellness-oriented workshops into educational and personal development programs, with the potential to improve cognitive performance and reduce stress among young people".

2.6 Education, Pedagogy, Didactics, Maths, Analytics and Statistics

Calculation Ability

A 12-month German study (Scholz et al., 2008) involved 53 students with learning difficulties (low IQ 70-85). Thirty-one were in the chess group and 22 in the control group, with the average age at completion 11.2 years (chess) and 11.4 (control). Calculation abilities improved significantly more in the chess group than in the control group.

Chang and Lane (2016) conducted a Texas, USA study entitled "There is Time for Calculation in Speed Chess, and Calculation Accuracy Increases with Expertise". They based this on two experiments that analysed 200 "speed chess" games.

"Calculation" was one of several abilities in which chess players performed well above the national average in a small-scale Hungarian study by Burjan (2017).

Rosholm et al. (2017) conducted a Danish study involving 482 students. In this study, 323 students received chess instruction to replace one maths period a week, and the 159 students in the control group continued with the maths lesson over 30 weeks. While there were positive results for other aspects of maths, there were no significant findings involving calculation abilities.

Calibration

Horgan (1987, 1990, 1992) conducted pioneering work in the USA exploring the link between children learning chess and their calibration skills. She showed that children are well-calibrated about their skill level because of the chess ratings system. Her 1990 paper indicated that better calibration is associated with better study habits. This paper also examined the role of feedback in calibration and the association with better performance and efficient study. Her 1992 paper was mainly concerned with calibration ability. Motivation and cognitive implications were also covered. Horgan noted:

> *Since players of good calibration know what they know and do not know, there is less defensiveness and fewer emotional barriers to learning. These players make appropriate attributions for success and failure. Their expectations are reasonable and are usually met. They have sophisticated intuitions about winning and losing, even in conjunctive situations. Players who achieve calibrated predictions know what they know and what work needs doing. They seek feedback directed specifically at weaknesses.*

Three thousand, three hundred and eighty-eight rated chess players aged 5-88 from 22 countries participated in a preregistered survey (Heck et al., 2024). Overall, chess players overestimated their chess-playing ability. However, upon examination of the data, low-rated players overestimated their ability the most, while the high-rated players were well calibrated. The researchers concluded that overconfidence exists, even in an inhospitable environment.

Didactic

Noir (2002) from France wanted to know “under what conditions must the didactics of a body of knowledge satisfy so that the transferability of cognitive skills developed in this knowledge in action is efficient?” Noir tested this by identifying various cognitive processes activated during chess, testing which cognitive skills were transferable, building a didactic framework for transfer, and finally testing it with two classes and two weekly lessons over seven months. Noir presented his results over five chapters in his thesis.

An Indonesian study by Mahmudov et al. (2020) concluded that the didactic possibilities of chess need to be better researched. Chess mastery is related to developing cognitive skills, and chess helps model creative and heuristic thinking processes.

A study from Santiago, Chile covered the steps of establishing ethnographic modelling through semi-structured interviews among chess players for teacher training in mathematics programmes (Sepúlveda-Herrera & Huincahue, 2024).

Heuristics

An Italian study involved 931 primary school students divided into three groups: chess instruction; chess instruction with mathematical problem-solving heuristics; and a no-chess control group. Results indicated that the "heuristics" group outperformed the other two groups, indicating that teaching general heuristics may facilitate transfer (Trinchero & Sala, 2016).

Campitelli et al. (2014) contributed to the IQ vs. deliberate practice debate by proposing a model incorporating "domain-specific pattern recognition and heuristics" as explanatory variables.

Numeracy

A study from Greece (Giouvantsioudis, 2024) involved a systematic literature review that investigated chess participation and improvements in students' maths skills. Positive results were found in the 12 studies that met the research requirements.

Researchers from Italy (Malvasi et al., 2022) followed up on a study by Trinchero and Sala (2016). A total of 4845 Italian teenagers completed a questionnaire, and 12 in-depth interviews were conducted with high school teachers. Because students demand greater motivation, and the perceived benefits for them of learning chess, the researchers claim that training of chess teachers should be given greater attention.

Pedagogy

Xalilovich (2023) discussed the pedagogical necessity of developing schoolchildren's intellectual abilities and the importance of including chess from preschool in the process. Psychological-pedagogical tools and literature were used to assess the development of memory and logical thinking in the classroom in the chess group of children of primary school age (Masharipova & Matiusupov, 2023). Both studies are from Uzbekistan.

Noir (2002), in his thesis involving chess and children, proposed a dual pedagogic strategy, merging teacher-to-pupil instruction and hands-on practical learning, resulting in a more profound understanding. He questioned and discussed whether computer games are helpful support tools for pedagogy.

A Brazilian qualitative study (de Freitas Ferreira, 2023) investigated using chess in a high school as a "pedagogical didactic resource" to facilitate learning. The study involved a semi-structured questionnaire for students and an interview with the researcher for teachers. The researcher concluded that learning chess benefits students in many ways, including memorisation, attention, concentration, reasoning and decision-making.

An Armenian study (Gevorkyan et al., 2023) used current and previous empirical studies, sociological surveys, structured interviews, focus groups, testing and questionnaires conducted over several years to inform the pedagogy of their "chess in schools" project. The research indicated a need to "integrate chess with maths and other subjects" owing to the likely benefits of decision-making, creative thinking, cooperation and critical thinking.

A Chess Development Project (CDP) instigated by pre-service teachers in a South African university "helped create a safer, non-violent, and more supportive school environment" (Esau, 2023). The participatory action research (PAR) project suggests that universities can contribute to their local communities. The researcher used field notes, student assistant notes, questionnaires, transcribed recordings and interviews, which ultimately resulted in the introduction of a sport: chess. The project resulted in a greater sense of community, raising awareness of the challenges.

Many people associate men rather than women with brilliance (Jenifer et al., 2024). It has been found that field-specific ability beliefs (FABs) associated with brilliance are already present in primary school. There is a need to understand these beliefs' long-term effects and sources. "The early emergence of brilliance-oriented math FABs and their negative relation to math motivation highlights the need for research that examines ways to ameliorate these beliefs." A study involving children learning chess and their ability beliefs is warranted.

A project from Poland (Szczepanik-Ninin, 2024) is unique in that it presents chess learning in a friendly context involving physical education, maths, art activities and the Polish language.

Romanova et al. (2018) from Ukraine note that chess effectively activates mental activity. They propose using chess therapy in training and aligning it with current methods to prepare future social pedagogies.

Probability

Calibration and probability theory are closely related. Horgan (1992) was impressed that young children understood that the chance of losing one game might be low, but the more rounds played, the higher the probability of losing a game. Teachers often use this type of example to explain diminishing probability theory. Horgan (1987) noted that the chess rating system "provides a real-life lesson in probability theory for children".

Gerdes and Gränsmark (2010), researchers from Stockholm University, in a study conducted at the Institute for the Study of Labor in Bonn, used an international database of 1.4 million chess games and probability theory when discussing gender issues in chess. For example, they found that, although it reduced their winning probabilities, males chose aggressive strategies against females. Their research found that, for a male, a solid strategy "has a 1.5 percentage point higher probability of winning compared to not using such [a] strategy".

A Spanish study by Rodríguez-Muņiz et al. (2022) involved 31 fifth-grade students aged 10-11 and subjective probability theory. It was found that students could make probability judgements with numerical support, respond effectively to additional information and refrain from judgement when insufficient information was provided.

2.7 Children with Special Needs, Difficulties, Disabilities or Disadvantages

Children in Conflict with the Law (CICL)

A study in the Philippines (Lastima & Gayoles, 2020) used chess training to assist the psychological wellbeing of CICL. Nine students undertook chess lessons for two hours a week for 10 weeks, and a control group of 12 who did no chess also participated in the study. It found that chess training improved the psychological wellbeing of CICL, but not at a statistically significant level. The authors claim that chess is a fun activity that helps children with CICL to be more resilient, improve their social connectedness and thrive.

Disabilities

A study in Texas, USA by Barrett and Fish (2011) featured 15 6th, 7th and 8th grade special education maths classes that undertook 30 weeks of chess instruction and a control group of 16 who did not. The chess group achieved a significant result for four tests: end-of-year course grades; Texas Assessment of Knowledge and Skills (TAKS) math scale scores; and percentage scores on two specific TAKS math objectives. The researchers warned that the scope of the study was limited; there was a small sample size and a lack of randomisation.

Chess players with a high level of motor impairment rely on a person to move their pieces in tournament chess (Pozzi et al., 2024). The proposed robotic assistant is controlled through an intuitive graphical user interface, thus allowing the motor-disabled person to have independence.

Dyslexia

Sixty-two subjects (of whom 31 were dyslexic), aged between 10 and 44, participated in an experiment conducted in the USA to determine whether learning to play chess helps people with dyslexia (Rello et al., 2016). An online chess game was designed. Participants were required to complete lessons regarding chess practice and theory and to play chess against a computer. While people with dyslexia spent more time practising and playing chess than their counterparts, there was no evidence of improvement in other performance measures.

Learning Difficulties and Disabilities

A German study involving children with learning difficulties was briefly discussed under the calculation abilities heading (Scholz, 2008). The study, which involved school classes from four German schools, found that, for written and gap tasks, calculation and concentration abilities developed equally well between the chess and the control groups. However, the chess group did significantly better in simple addition and counting. The researchers were encouraged to extend chess lessons to a larger group.

Research from Armenia discusses the difficulties elementary school children have with learning chess owing to its difficulty (Sargsyan & Khachatryan, 2024).

Risk of Academic Failure

A study involving 38 students aged 8-12 at risk of academic failure from three elementary schools in Seoul, South Korea included 18 students with an average age of 9.71 years in the chess group and 20 students with an average age of 9.74 in the control group (Hong & Bart, 2006). Results of the TONI-3 tests indicated a significant relationship between chess skill rating and improved cognitive scores. The researchers concluded that children at risk of academic failure should continue to receive chess instruction.

Special Needs/Special Education

In recent years, perhaps motivated by their national chess team that had placed first at international Chess Olympiads (ahead of powerhouses such as China, India, Russia and the USA), Armenia has introduced a national "chess in schools" programme. Their Chess Research Institute has conducted several studies (mainly in the capital, Yerevan) related to children with special educational needs (SEN). While the programme has had some positive indicators, there needs to be stronger evidence of success, especially in regional areas (Charchyan & Karapetyan, 2022).

Scholz et al. (2008) have been cited elsewhere in this systematic literature review. Their study indicated that learning chess can be a "valuable learning aid" for children with disabilities.

Visually Impaired

Twenty-six visually impaired students participated in a trial by Aydin (2015). The chess group of 12 students undertook chess lessons at a Turkish school for four hours per week over 12 weeks, and the 14 in the control group did not do chess. There was a positive result for the chess students in maths scores at the level of .002. Standard deviation, arithmetic mean and the Wilcoxen test (a nonparametric rank test for statistical hypothesis testing) assessed progress.

Another Turkish study by Ekizoğlu et al. (2023) examined the possible effects of learning chess on rehabilitating the visually impaired. A code list was prepared to develop interview questions. Analysis of the interviews showed a positive emotional impact of chess instruction on participants. The emotional impact was particularly strong for those experiencing difficulty with social integration. More generally, participants reported that chess helped their self-esteem and social skills.

Balata et al. (2015) conducted a study in the Czech Republic involving five advanced blind chess players and semi-structured interviews, resulting in 114 findings. These included research on developing accessibility aids, the mental images of blind chess players and chess training specifically for blind people.

2.8 Gender

Chess has evolved as a fertile ground for research on gender issues. Galitis (2002) reported on a chess club in Melbourne, Australia that commenced with approximately 60 students aged 7-12 and equal gender numbers. After one week, the number was down to 40, with approximately one-third girls. By the end of the year, the number was 26, of whom only three were girls. Eventually, the female author/chess club organiser concluded that low female participation in the mixed chess club was due, at least in part, to male harassment.

A study in Tennessee, USA (Chitiyo et al., 2023) involved 1,286 students across elementary, middle and high school. A retrospective pretest survey was administered. Perceived benefits were consistently higher for elementary students. Across grade levels, boys had higher enjoyment and confidence in their chess ability, while girls had higher engagement in learning resulting from chess instruction.

An English study by Bilalić et al. (2009b) reported that, although the performance of the 100 best male German chess players was better than that of the 100 best women, 96% of the variance could be accounted for owing to the greater number of male participants, leaving just 4% for cultural, environmental or biological factors to explain.

The primary purpose of a study conducted in Holland and Belgium by Barbier (2020) was to study the profile of female chess players compared to males. Seven hundred and nine chess players (male 544, female 164, other 1) participated in an international survey that examined gender expectations, and the image and profile of a chess player. Females, because they are in the minority and stand out, have advantages and disadvantages. Owing to their low number, it is harder to find female role models. Preconceived ideas that females are worse at chess sometimes lead to a change in playing methods, gendered treatment and pressure from the feeling that one is representing all females. Generally, females felt valued as serious chess players in the community.

Swedish researchers Gerdes and Gränsmark (2010) employed a panel data set of 1.4 million chess games collected over 11 years, which included ELO chess ratings data (indication of playing strength). An analysis revealed that women are more risk-averse than men, and men choose more aggressive strategies when playing against women. Compared to men, women avoid aggressive strategies. When they are forced to do so, they are not effective. However, it was found that, when men adopt aggressive strategies against women, they reduce their winning probability.

A Colombian study by Martínez Ramírez (2021) found that the group of women chess players who challenged themselves became the most improved. Those who opted to play in more challenging (male/female) events improved significantly, in contrast to those who stuck to “women only” events. A consideration is the need to attract (and retain) female players to chess and to develop good female role models. “Female only” chess tournaments have their place. The author noted that “the existence of exclusively female tournaments is vital for the continuation of female participation in chess, as well as to attract new female players to the circuit”.

An American study by Arnold et al. (2023) found significant bias against female chess players (especially youths). Parents and mentors in the study believed that the girls' highest potential rating was lower than that of the boys. They also believed that girls were more likely than boys to drop out of chess owing to perceived low ability.

A primarily English study by Backus et al. (2023) utilised a "quality of play" programme to measure the strength of moves made in a game, with moves generated by a powerful chess programme in the same position. Results indicated that "the mean error women commit is about 11% larger when they play against a male". The researchers also found that men often keep playing against women in positions where they would resign if they were playing a male.

Another English study by Stafford (2017) examined data from over 5.5 million international tournament chess games and found no evidence of a stereotype effect for females playing males. Further, women tend to outperform expectations when playing men. When examining national chess leagues, it was found that the level of challenge, player age and prevalence of female role models did not influence performance "when women play men versus when they play women".

Stereotype threat was also the subject of a paper by Smerdon et al. (2020). The researchers noted that Spencer et al. (1999) and Steele et al. (2002) support stereotype threat, but that Cullen et al. (2004) and Finnigan and Corker (2016) disagree. The researchers observe that, because women are under-represented in tournament chess and men are, on average, rated higher, tournament chess is ideal for assessing the stereotype effect. They conclude that "it should be impossible to detect stereotype-threat effects by comparing women's actual performance with their performance expected based on Elo ratings because those Elo ratings should already have captured the stereotype-threat effects the researcher wants to measure".

Chassy (2023) notes that an investigation utilising 140,367 Elo rating data provided by the Federation Internationale des Échecs (World Chess Federation - FIDE) found an advantage for males. However, a performance analysis revealed that, when both genders reach peak performance, the "average rating" and the "proportion of experts" are equal. Researchers have looked at other explanations, including "nurture", "nature", "innate traits" and "inequities in training conditions".

Brancaccio and Gobet (2023) conducted a systematic literature review on the gender issue in chess, and concluded that none of the current explanations can completely explain gender differences. They indicate that there is a gap in performance between males and females. They made a case for four explanations: biological, sociocultural, statistical and individual differences, but none can provide a complete answer. Future research should focus on experimental studies rather than on chess database searches.

Elo chess ratings and chess tournament data were used to analyse gender differences in chess players and to gauge whether age and practice were factors. Participation rates were not found to be a factor for males or females, but age and practice were a factor for females, but not for males (Blanch et al., 2015).

A sample of 150,000 elite chess games was examined. It was found that women vs women and women vs men games were substantially less likely to end in a draw than men vs men games. These findings suggest that the results in men vs men games are more likely to be prearranged draws (Dilmaghani & Smerdon, 2024).

A huge database of around 22 million classic chess games was examined to study gender differences in cognitive performance and competitive participation. Regarding their personal bests, it was found that males and females perform very differently around the margins in both (González-Díaz et al., 2024).

The World Chess Federation instigated a gender equality index designed to compare and evaluate gender equality in world chess (Smerdon et al., 2023).

2.9 Artificial Intelligence (AI) and Information Technology (IT)

AI

A study by Anbarci and Ismail (2024) proposes a novel artificial intelligence (AI) method for breaking ties in chess. It involves comparing the quality of players' moves against those proposed by chess engines. If there is a tie, the player with the higher quality moves wins.

A unique learning approach requiring only 100 games to be effective shows potential for inclusion in "human-centred AI applications", and promises to "make personalised chess training more accessible" (August, 2024).

Bilalić et al. (2024) analysed a database of 11.6 million chess move decisions by elite chess players during the introduction of personal computers and the Internet in the late 1990s and later with the introduction of deep learning-powered chess engines in the late 2010s. Chess players' improvements matched those of AI over the entire period, but not steadily. Recently, human improvements have not yet matched those of neural network-powered engines.

The computer programme AlphaZero uses AI and machine learning (reinforcement learning) to achieve chess performance on standard hardware well ahead of humans. Hybrid evolutionary algorithms are likely to improve chess-playing AI systems further (Chole et al., 2024).

Koenig (2024) discusses the improvement in chess engines and their possible future use. Through chess research, scientists were inspired to use teamwork. The researchers believe there may still be ways to improve AI through chess by making it more closely resemble human intelligence, or at least as a testing ground for improving AI technology.

A chess algorithm, Maia, was trained to make human-like moves and was perceived by human chess players to achieve this when compared to other chess engines. The researchers were not able to identify differences in underlying processes as perceived by humans in a Turing Test experiment (Koerts (2024).

Peng (2024) uses AI in chess decision-making to examine whether it can be used to improve management decision-making. It examines how a possible relationship between decision-making automatism (DMA) and decision-making dynamism (DMD) could positively influence innovation in management decision-making.

Tang et al. (2024) claim that their "unified framework significantly enhances the alignment between AI and human players across a diverse range of expertise levels, paving the way for deeper insights into human decision-making and AI-guided teaching tools".

A paper by Thakur et al. (2024) describes developing a next-generation chess engine using AI. The study highlights the "effectiveness of evolutionary algorithms in optimising position evaluation".

Tirado and Pilatti (2024b) have shown that interactive computational systems have enhanced human intuition and that, with AI integration, historically high levels of chess performance are being achieved.

Finance, law and healthcare are just three of several domains where human decision-making is supported by algorithmic advice (Poulidis et al., 2025). Because powerful chess engines were available, chess was used as a model to disentangle roles. The authors claim their study's findings have significant implications for the deployment of algorithmic signals to improve decision-making in practice.

IT

A paper by Gundawar et al. (2024) involves model predictive control (MPC) rollout and reinforcement learning (RL) methodologies, which the authors claim provide an additional layer of intelligence on top of the engines upon which they are based.

A Polish work by Milosz and Kapusta (2024) contributes to the field of cognitive modelling and educational technology by providing a new way of evaluating chess puzzle difficulty. It highlights the importance of deep learning models in education.

Monroe and Chalmers (2024) examined the important relationship between chess and transformers, especially the importance of position representation within the attention mechanism. The researchers claimed that "domain-specific enhancements can in large part replace the need for model scale, while also highlighting that deep learning can make strides even in areas dominated by search-based methods".

A project by More et al. (2024) aims to address the challenges of data trust, security and game record management. In part, it aims to thwart cheating activities. Positively, by providing the global online chess community with a robust sense of security, it seeks to encourage broader participation.

A study by Omori and Tadepalli (2024) used a dataset from Lichess, which includes over one million games, to estimate players' chess ratings using chess moves and clock times. The study aims to provide a more accurate rating system, particularly for players either improving rapidly or inactive.

A thesis by Siven (2024) traces the development of technologies related to chess computers and algorithms through AI and discusses emerging technologies (e.g., quantum computers and neural networks).

Tirado and Pilatti (2024a) from Brazil investigate whether the systematic use of a chess learning platform, in this case “Lichess”, significantly improves cognitive skills.

A study by Ruoss et al. (2025) introduced a new programme named “ChessBench”, which uses 10 million chess games with 15 billion data points obtained from Stockfish 16. It claims a Lichess blitz elo rating (playing strength) of 2895. It claims that, “although a remarkably good approximation of Stockfish’s search-based algorithm can be distilled into large-scale transformers via supervised learning, perfect distillation is still beyond reach, thus making ChessBench well-suited for future research”.

While the body of studies in the systematic literature review was collected to keep the researcher up to date, in the context of the researcher’s perception of a fragmented scene, the primary aim of this systematic literature review was to provide existing and potential researchers in the field of children learning to play chess with a comprehensive view of the current ‘state of play’ of the studies relating to children learning chess and related perceived benefits. There is some crossover into adult chess and technology.

2.10 Summary of the Main Body of Literature

The literature review reveals the vast scope and breadth of chess research, and attributes many benefits to the game. This study is concerned with research on the relationship between learning, practising and competing in chess and literacy and numeracy scores. As such, a scoping literature review was conducted to frame and narrow the scope of the relevant literature, and to inform the conceptual model and research questions guiding this study.

The following scoping review uncovered a large body of literature relating to children learning chess and possible benefits for their literacy and numeracy scores. It provides further evidence to justify a study into whether “far transfer” may exist. The scoping review and the preceding systematic literature review provide a comprehensive overview of empirical chess research, primarily involving chess and children.

CHAPTER 3: LITERATURE REVIEW AND SCOPING REVIEW

3.1 Introduction

Chapter Two presented a general overview of chess-related research and its lines of enquiry. The scope of Chapter Two is broader than that of this study's topic. The inclusion of Chapter Two is justified as it provides a broader context within which this study's scope falls. This chapter focuses on the literature associated with the topic of chess in schools, the impact of chess on standardised literacy and numeracy scores and culminates in a paper that is under review which presents the conceptual framework guiding this study.

3.2 Historical Background

It is believed that chess originated in India during the sixth century CE and quickly spread to China and Persia (Eales, 1985, pp.13 and 35, citing Hyde's *De Ludis Orientalibus*, published in 1694). Eales also established that chess spread throughout the Muslim world around 750 CE (p. 37) and to England and Western Europe by the 12th century CE (p. 50). The game remained the same until around 1500, when the only major rule changes in its history were conducted, aiming to "speed up the early stages of the game without transforming the tactics of play as a whole" (p. 71).

There appears to be no evidence of playing chess in Australia before the 19th century. However, the M. V. Anderson Collection at the State Library of Victoria, which is believed to be the third largest chess collection in the world, includes a leaf from Caxton's *The Game and Playe of Chess* from 1483, and a 1561 edition of Ruy Lopez's work *Libro de la inuencion liberal y arte del juego del axedrez muy vtil y prouechosa* (literally translated as *Book of liberal invention and art of the game of chess*).

Until the mid-1990s, Australia was well behind the major chess nations, but since then it has started to catch up. Before 2008, apart from the late Walter

Browne, who obtained his Grandmaster title in 1970 and who represented Australia at the Chess Olympiad in 1972 and then emigrated to the USA, Australia had two Grandmasters (Ian Rogers and Darryl Johansen), who obtained their titles in the 1980s. Now there are eight more: David Smerdon, Anton Smirnov, Moulthun Ly, Bobby Cheng, Temur Kuybokarov, Zhao Zong-Yuan, Max Illingworth and Justin Tan. Australia also has had three female Grandmasters: Daniela Nuțu-Gajić, Julia Ryjanova and Jilin Zhang. Bobby Cheng became the first and so far the only Australian to win a world age title (under 12) in 2009. In 2013, at age 13, Anton Smirnov became an International Master. David Smerdon drew with world champion Magnus Carlsen at the 2016 Chess Olympiad. Nevertheless, Australia is still only ranked around 40+ (open and women's sections) in the Biannual Chess Olympiad, based on World Chess Federation (FIDE) chess ratings (indication of playing strength). Realistically, only full-time competitive chess players (players rated approximately 2700+) have any chance of reaching the top echelons of world chess. To date, no Australian has reached this playing level.

Today, China and India dominate the chess world, with Russia recently losing ground and the USA always competitive at the top level. Several countries located along the Silk Road retain their deep chess culture. Armenia surprised the chess world by winning the Chess Olympiad (teams event) in 2006, 2008 and 2012.

The popularity of chess continues to grow. Estimates of the worldwide number of chess players vary, but online chess site *chess.com* states that approximately 605 million adults play chess regularly (a figure stated by YouGov.com in 2012). Most surprising is the percentage of adults who currently play chess (either weekly, monthly or during the past year): 12% in the UK; 15% in the USA; 23% in Germany; 43% in Russia; and 70% among the 121 million Indians considered ABC1 by advertisers.

The movie *Queen's Gambit* was the impetus for a resurgence of interest in chess. As of July 2025, the *chess.com* online counter indicated they had 219 million members. While there is no definitive research, these figures and personal observations suggest that, at the very least, 10% of the population worldwide can play a half-decent game of chess.

3.3 Chess in Queensland Schools

The improvement in Australian chess is due, at least in part, to the increase in junior participation. For example, in Queensland there were 113 students with an active Queensland Junior Chess rating in 1993; in 2019, there were 3,806 (players are removed from the list if inactive for 18 months). In 1993, there were fewer than 200 participants in inter-school chess; in 2019, there were between 3,000 and 4,000 each term (source: Chess Association of Queensland *caq.org.au* and Gardiner Chess *gardinerchess.com.au* websites). This growth has been mainly due to the advent of a growing number of businesses that have been providing chess teaching services to schools since the late 1990s. Some services are provided during curriculum time, while most occur before or after school as an extra-curricular activity.

Whether schools should provide chess tuition in or out of curriculum time, or even provide chess at all, has long been the subject of pedagogical debate. This debate normally centres around, but is not limited to, whether learning to play chess helps children with their cognitive abilities. However, from the number of schools that and students who enter the inter-school chess tournaments term after term, year after year, it can be deduced that educators see benefits for students.

A survey of school principals, schoolteachers and parents of children learning chess in Queensland schools conducted by the researcher in 2016 (Gardiner, 2018) found that over 300 of the 316 responders believed or strongly believed that learning chess helps students with a range of thinking and other skills.

The Queensland Junior Ratings List (QJRL) is an important element of this study. Rating lists around the world indicate the playing strength of each player in relation to all others on that list. The QJRL is uniquely placed. Whereas most rating lists consider only games played with long time controls (for example, one hour for each player), the QJRL includes all games, even those as short as five minutes a side. As only a small proportion of junior chess players in Queensland enters tournaments with long time controls, the QJRL has data for many more students from many more schools than would otherwise be the case.

3.4 Chess Players and their Thinking Skills

Since the late 1930s, researchers have been interested in the relationship between children learning chess and their thinking skills. Each move in a chess game presents an opportunity to solve a new problem, calculate, plan, strategise, synthesise ideas, analyse and use intuition (current researcher observations).

Much of the research focusing on chess and education has involved primary school children learning chess and its possible benefits in terms of their thinking skills. This is not surprising since chess is substantially about thinking, particularly cognitive thinking. Indeed, the survey conducted by Gardiner (2018, pp. 63, 115) indicated that many people believe that playing chess helps children with their thinking skills and other benefits. However, this belief has yet to be proven despite many similar studies, especially those involving primary school students at the beginner level.

The seminal work on chess and thinking skills was conducted by Dr Adriaan de Groot, a prominent Dutch psychologist and, for three decades, a professor at the University of Amsterdam. In the preface to de Groot's book, *Thought and Choice in Chess* (de Groot, 1978), Dr Sijbolt Noorda, President of the University of Amsterdam, noted:

> *His research contributed substantially to the development of psychology as an empirical discipline. To this day, the Dutch school system relies on aptitude tests proposed by De Groot in his book on selection processes in education. The book marks the transition of the psychological study of genius to the early beginnings of empirical cognitive science.*

There has been a continuous trail of research in this important domain stretching from de Groot, who studied the thought processes of Grandmasters in the late 1930s (work published in de Groot, 1978), Simon and Newell (1971), Chase and Simon (1973), de Groot et al. (1996) and Gobet and Simon (1996b) to the prolific work of Gobet and his colleagues since then. De Groot made a fundamental observation (1978, p. 334) that eventually led to chunking theory (Chase & Simon, 1973) and template theory (Gobet & Simon, 1996b):

> *It is only possible to perceive relatively large complexes as units or wholes because they are typical wholes to the perceiver: origin, function, significance,*

value, and/or prescribed treatment. Because larger units can be perceived as such, the subject can assume a complete position quickly.

This amounts to the skill of pattern recognition. Chase and Simon (1973) argued that it takes at least 10 years to build up this skill to become a Grandmaster (although several Grandmasters have achieved the title at 12 or 13). Seven Australian Grandmasters reported that, apart from pattern recognition, they use a wide range of thinking skills in a long chess game, which they identified from a thinking chart devised by Gardiner (2018, pp. 25-28). Cognitive skills were at the forefront.

3.5 Thinking Skills Possibly Associated with Learning to Play Chess

According to Frederiksen (1983, p. 363), teaching cognitive skills and imparting knowledge should be the most important goals for educational institutions involving students from elementary to graduate and professional schools. "Thinking allows us to take things we know or observe and turn them into new ways of understanding" (Adey et al., 2001, p. 2). McGregor (2007, p. 23) noted that good thinking is challenging, effortful and not easy, and requires practice. Robinson (2012) *states, "Cognitive abilities* are aspects of mental functioning, such as memorising and remembering; inhibiting and focusing *attention*; speed of information processing; and spatial and causal *reasoning" (p. 1)*.

Peng and Kievit (2020) asserted that, because educational achievements are affected by improved academic skills, especially in reading and mathematics, "academic achievement plays an important role in child development" (p. 15). They also cited the factors they considered important for academic performance: cognitive abilities, including but not limited to working memory (Peng et al., 2018); reasoning (Sternberg et al., 2008); and executive function (Best & Miller, 2010).

Horgan (1990, p.1) argued that studying childhood expertise is essential for several reasons:

First, models of expertise in general, and of chess skill in particular, must be able to account for high levels of competency among young children. Also, understanding how they acquire their skill is important theoretically and may have important practical implications for enhancing other types of learning.

From this perspective, many ways of thinking could be associated with learning to play chess. These may include cognitive, critical, creative, innovative, strategic, logical, systemic, analytical, convergent, planning, conceptual, evaluating, synthesising, reasoning, intuition, foresight, concentration, metacognition and problem-solving.

Most research concerning primary school students' chess and thinking skills has focused on cognitive thinking. This is evidenced by the literature review of Nicotera and Stuit (2014), where 23 studies met their inclusion requirements. These studies were P-12 chess interventions with academic, cognitive and behavioural outcomes, and they measured the following skills (some more than one): Maths 13, Cognitive Skills 9, Reading 8, Behaviour 5 and Science 1.

3.6 Studies and Meta-Analyses on the Topic of Children Learning Chess and their Cognitive Skills

Most studies of children learning chess and of possible improvements in their cognitive skills have been conducted with primary school students. Many were reviewed by Gardiner (2018, pp. 11-19). Studies by Burjun (2017), Rosholm et al. (2017), Islam et al. (2021), Stegariu et al. (2019) and Trinchero and Sala (2016) also involved primary school students. Very few have looked at secondary school students. Importantly, all these studies have primarily involved beginner chess players, with only an incidental sprinkling of more advanced players.

3.7 Far Transfer between Domains

Perkins and Salomon (1992) noted that "transfer is crucial to education, which generally aspires to impact on contexts quite different from the context of learning" (p. 2). They provided an explanation of the transfer of learning (1992):

> *Transfer of learning occurs when learning in one context or with one set of materials impacts performance in another context or with other related materials. Transfer is a key concept in education and learning theory*

because most formal education aspires to transfer. Near transfer refers to transfer between very similar contexts, as when students taking an exam face a mix of problems of the same kinds that they have practised separately in their homework. Far transfer refers to transfer between contexts that, on appearance, seem remote and alien to one another. For instance, a chess player might apply basic strategic principles such as 'take control of the centre' to investment practices, politics, or military campaigns. (p. 3)

Gobet and Sala have been at the forefront of research into the possibility of children learning chess and gaining improved cognitive skills. Their paper, "Does Far Transfer Exist? Negative Evidence from Chess, Music, and Working Memory Training" (Sala & Gobet, 2017c, p. 519), suggests that policymakers and researchers should consider stopping wasting resources in this area of research. They contend that researchers should determine precisely which areas of cognitive thinking underpin expertise rather than finding a way to improve general cognitive ability.

In their paper "Far Transfer, Does it Exist?" (Sala & Gobet, 2017b), they observed that:

… the widespread notion that practising any cognitively demanding activity enhances one or more cognitive skills beyond the trained activity has little empirical support. Practically, the unlikely occurrence of far transfer suggests that the most effective way of improving a skill is to train that particular skill. (p. 2)

Furthermore, Sala et al. (2019p.3) stated:

Knowing whether and under what conditions far transfer occurs would represent a breakthrough in education and training. In general, understanding the mechanism of transfer is a major challenge in cognitive science with profound theoretical and societal implications

and concluded (also p.17): "Near transfer occurs in all the examined populations but, interestingly, young populations seem to benefit from the treatment (i.e., working memory training) more than adult populations". Regardless of the type of cognitive training program and population, they found no evidence of far transfer. "These findings are consistent with substantial research into education, skill acquisition, and expert performance" (p.17). Programmes studied included video games, music, chess, and exergames.

3.8 Heuristics to Aid Far Transfer

In their paper "Chess Training and Mathematical Problem-Solving: The Role of Teaching Heuristics in Transfer of Learning", Trinchero and Sala (2016) suggest their results "foster the hypothesis that a specific type of chess training does improve children's mathematical skills and uphold the idea that teaching general heuristics can be an effective way to promote transfer of learning" (p. 655). Also, heuristics assist beginner chess players to "recognise and interpret" chess positions, to "reduce the moves to analyse" and to play good moves "without overloading players' cognitive system" (p. 665).

Teachers are continually looking at innovative ways to improve how they impart knowledge to students. Pedagogies can include games. Chess is one such game that has long attracted the interest of educators. "Effective pedagogies focus on developing higher order thinking and meta-cognition and use dialogue and questioning to do so" (Pearce & Husbands, 2012, p. 9). According to Peterson et al. (2018), pedagogy is at the "heart of teaching and learning" (p. 4). They assert that reviewing and updating pedagogies prepares students for contemporary challenges. "It is possible that serious games are more effective than conventional instruction in terms of knowledge retention … but not in motivation" (Peterson et al., 2018; c.f., Wouters et al., 2013). Peterson et al. (2018) and Hainey et al. (2016) note innovation in primary education tends to be more focused on serious games involving strategy, solving puzzles and role-playing, rather than the entertainment games. Their literature review suggests serious games impact, especially knowledge acquisition, although they do not provide quantitative meta-analyses. By prompting learner motivation through pedagogies that appeal to young learners, areas of education linked with innovative learning ecosystemscan be activated (p.109).

Metacognition is especially important because it affects the retention, acquisition, comprehension and application of what is learned, as well as critical thinking, learning efficiency and problem-solving. "Metacognitive awareness enables control or self-regulation over thinking and learning processes" (Hartman, 1998, p. 1). "The development of metacognitive skills is not expected to set in before the age of 11–12 years" (Veenman & Spaans, 2004, p. 162; see also Alexander et al., 1995; Armbruster et al., 1982; Berk, 2003; Campione et al., 1982; Cross & Paris, 1988; Flavell & Wellman, 1977; Kuhn, 2000; Siegler, 1998; Veenman et al., 2004). "Spontaneous construction of metacognitive skills only starts to awaken at a late elementary school age" (Sungur & Senler, 2009, p. 46). Suppose the development of metacognitive skills only starts to emerge around late primary school (approximately 11-12 years old). In that case, it might help explain why many studies involving primary school students learning to play chess have shown no benefits for their cognitive skills.

Panaoura et al. (2003) report, "In modern psychological literature, the term 'metacognition' has been used to refer to knowledge about cognition and regulation of cognition" (p. 437).. Also, "Improving either metacognitive knowledge or metacognitive regulation improves learning" (p. 438). Moreover, according to Flavell (1979), "metacognition improves by practising it or by practising other processes, which are not metacognitive themselves, but which indirectly promote metacognitive ability". Sungur and Senler (2009, p. 57) contend that, as students accept more challenging tasks, they metacognitively gain knowledge of cognition and regulation. Schuster et al. (2020) state that "metacognitive skills are task-general and transferable to a wide variety of learning tasks" (p. 455).

One strategy to foster far transfer is "bridging". The instruction encourages making abstractions, searches for possible connections, mindfulness and metacognition. This emphasises deliberate abstract analysis and planning (Perkins & Saloman, 1992, p. 10). "Findings of studies into the effects of metacognitive scaffolding have shown that scaffolding can improve the learning outcomes of individual learners in innovative learning arrangements" (Molenaar et al., 2011, p. 786 ; see also Azevedo & Hadwin 2005; Azevedo et al., 2008; Bannert, 2006; Bannert et al., 2009; Lin & Lehman, 1999; Veenman et al., 2005). Molenaar et al. (2011) assert that scaffolds can be delivered by a tutor, by a virtual agent, on paper or through a computer: "In innovative learning arrangements, scaffolds are often delivered by computers" (p. 787). Scaffolding is defined as providing assistance to a student on an as-needed basis, fading the assistance as the student's competence increases (Molenaar et al., 2011, p. 786; see also Wood et al. 1976). Most serious chess players use a standard chess programme such as Chessbase to help with their game analysis, knowledge of theory and match preparation.

In long games, the laws of chess demand that players write down all their moves on a scoresheet. Horgan (1987) noted,

> *Chess offers unusual opportunities for process feedback. In tournaments, players write down all their moves. They then replay their games with coaches or other players, trying rejected alternatives and testing what the outcome might have been. This multi-level feedback and evaluation benefits all learners and is far superior to knowing whether one won or lost the game.* (p. 5)

In the current researcher's experience, those who improve their chess the most regularly review their scoresheets. In their book *Habits of Mind Across the Curriculum: Practical and Creative Strategies for Students*, Costa and Kellick (2009) suggest a list of how teachers would like their students to be, as follows:

> *Be independent thinkers; think before they act; be more self-motivated; be more inquisitive; pay attention to detail; take pride in work; be more diligent and persistent; enjoy working through the work; think for themselves; not always follow another's lead; generate their own thoughts; be self-directed, use strategies of problem-solving; transfer knowledge and apply to new situations; have confidence; be able to take risks; support answers so that they can show evidence of their thinking; communicate with each other; work it out together.* (p. 2)

Through a lifetime of involvement in chess, the current researcher contends these characteristics go a long way towards accurately defining chess students who go well beyond the beginner stage and become serious about their chess.

Gauvain and Rogoff (1989) suggested that the experience of working in a collaborative situation encourages the development of metacognitive abilities such as planning (pp. 139–51), from McGregor (2007, p. 225). These arguments regarding collaboration and metacognitive scaffolding in chess indicate that learning may result from regular support by analysing scoresheets with a chess tutor, with more capable peers or alone with computer analysis. Horgan (1987) observed that feedback is an important aspect of learning and improving one's chess: “Going over games in detail with an expert and replaying games with different strategies offers the opportunity for rapid improvement” (p. 3). An excellent lesson in maximising skills is to go through games with a chess coach or a stronger player and to analyse the moves objectively: “Children learn to be objective about their own performance” (p. ??).

Belenky and Nokes-Malach (2012) posit that “students’ motivations can lead to different learning outcomes, an important first step in developing a theory for how motivation can influence and interact with cognition” (p. 426). “Students' intrinsic value and motivation to learn is an important component to be considered in our models of how students come to use different cognitive strategies and become self-regulating learners” (Pintrich, 2000; see also Meece et al., 1988; Nolen, 1988).

> *Students' metacognition is highly related to their level of motivation and classroom environment perceptions. Accordingly, the level of student motivation in terms of goal orientations, competence expectations, and classroom environment perceptions can play an important role in elucidating the variation in students' metacognition.* (Sungur & Senler, 2009, p. 48)

It is suggested that more advanced chess players are highly motivated to improve their chess ratings. Being competitive, they may also be highly motivated to do well in cognitive testing, especially their final exams leading to university entrance.

3.9 Discussion re Scoresheets, Far Transfer, Heuristics, Habit, Motivation and Meta-Cognitive Scaffolding

At some point in their development, many chess players make their scoresheets, along with assistance from chess tutors, opponents, computers and books, the focus of their chess development, which becomes a habit. The habits of mind and metacognitive scaffolding developed over the years through this process may be an effective heuristic, resulting in improved metacognitive skills and better cognitive scores for motivated students. If this is the case, the naturally occurring heuristic (regularly analysing one's scoresheets) is preferable to specifically teaching heuristics to encourage far transfer. This idea could profoundly affect 'chess in schools' programmes and teaching pedagogies. If this theory is correct, it would incentivise parents to support their students in pursuing their chess even when they get very busy with school studies in their high school years. Further, it would be a strong argument for schools to implement a chess programme encouraging students to take their chess as far as they wish.

However, chess is not for all students. The current researcher's experience suggests that children, not teachers or parents, decide if the children want to take chess seriously. From significant first-hand experience, the researcher strongly agrees and identifies with these observations of Poston and Vandenkieboom (2019, pp.21-22):

> *The goal of the parent or educator should be to spark an interest within the child to learn the game of chess, which can be done via chess club or class, but just as easily at home or during recess, then encourage the child to attend a competitive/rated tournament—most tournaments have a beginner section that will have other first-time players. From our experience, these tournaments are what drive kids to become serious about chess and ultimately learn it. For most kids, their first tournament experience is the same whether they win or lose; they either become hooked and want to continue learning chess and playing in tournaments, or they are not interested and they should hence move on to another activity. From our experience, it is exceedingly rare (and unwise) for a parent to spend an entire Saturday dragging an unwilling kid to one of these individual rated tournaments (i.e., one not related to a school team or run as part of a school curriculum). On the contrary, the majority of kids who play at these tournaments have to coerce their parents to bring them because those kids genuinely love playing at the tournaments. Their genuine interest, plus the explicit competition of the tournaments (the thrill of victory and the agony of defeat), drives them to truly learn the game of chess.* (pp. 21-22)

3.10 Poston and Vandenkieboom (2019) – Method, Results and Observations

A relatively recent study by Poston and Vandenkieboom (2019) examined elementary school students and followed their progress over several years. Importantly, this was the first study this century that looked mainly at more advanced chess students who learned, practised and competed at a higher level. Historical data from 2007 to 2014 from K-6 students at Aspen Elementary School, Los Alamos, New Mexico, were analysed. Standardised tests for maths and reading were used, producing 6,123 scores in maths and 6,242 results in reading. There were 854 students in the study, of whom 139 participated in chess club, and 77 participated in United States Chess Federation (USCF) rated tournaments. The researchers claimed statistically significant results. They found that:

> *… kids who come only to chess club receive a small (5%-10%) benefit in Math, whereas kids who play in rated tournaments gain substantially in Math (30%-50%) and significantly in Reading (10%-20%). The benefits also continue to grow as kids play more tournaments and/or increase their USCF chess rating.* (p.1).

Moreover, “Various comparisons showed a math score increase of more than six times the standard deviation of the results, which provides virtual certainty that there is a positive correlation between learning chess and test scores” (Poston & Vandenkieboom, 2019p. 21). This work involved students from just one school; there was no randomisation, and there was possibly a 'coach' effect.

The following systematic literature review and scoping review provide a thorough insight into the full range of chess literature, mostly involving chess and children, which necessarily crosses into adult chess.

3.11 Scoping review relating to the effect of chess instruction on standardised literacy and numeracy scores

Based on the literature review, a narrower scoping review was conducted to further synthesise research evidence related to the effect of chess instruction on standardised literacy and numeracy scores, clarify the research concepts, and identifying evidence gaps in the literature.

As noted above, instruction is widely promoted for enhancing children's academic performance, particularly literacy and numeracy. However, empirical evidence supporting a causal relationship between chess instruction and academic outcomes remains contested.

This scoping review (See paper under review in Appendix F) synthesises existing studies examining the association between learning, practising, and competing in chess and children's performance in standardised literacy and numeracy tests. Using the Joanna Briggs Institute scoping review methodology, 54 relevant studies were identified and evaluated.

Notably, robust studies, including a high-powered randomised trial (Jerrim et al., 2018), generally find negligible academic benefits. Moreover, most research focuses narrowly on novice-level chess players in primary education. The review identifies substantial gaps, recommending future studies investigate higher-level chess players over longer periods using rigorous experimental designs to conclusively assess the potential academic impact of chess practice.

3.11.1 Aims of scoping review

The scoping review aimed to investigate and synthesise the international literature on the relationship between children's chess instruction (learning, practising, and competing) and their literacy and numeracy outcomes, particularly as measured by standardised tests. The review seeks specifically to:

a) Assess the breadth and methodologies of existing studies examining educational benefits associated with chess.

b) Clarify and define key concepts, including educational benefits, numeracy and literacy outcomes, and the notion of far transfer as it relates to chess.

c) Identify and articulate clear research gaps that future empirical studies should address.

3.11.2 Method

A scoping review approach is particularly suited to this purpose, as it systematically maps existing evidence, analyses knowledge gaps, and defines study parameters and key concepts (Arksey & O'Malley, 2005; Munn et al., 2018). The study adopted a 'scoping review approach' documented by the Joanna Briggs Institute (JBI) (https://jbi.global/scoping-review-network). This method, widely employed for synthesising disparate research evidence, provides a structured process for synthesising research evidence, clarifying research concepts, and identifying evidence gaps in the literature (Peters et al., 2015; Arksey & O'Malley, 2005).

The scoping review was guided by the following research question: "Are there identifiable gaps in the current evidence regarding the effects of learning, practising, and competing in chess on children's literacy and numeracy outcomes?"

3.11.3 Results

Following the Joanna Briggs approach the study identified 54 relevant studies. These are presented in Table 2 with the full methodology and the results presented in the paper referenced in Appendix F.

Table 2: Eligible studies using the SCIPT framework

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
Frank	1974	Zaire	H	B	M	180	GATB, P.M.A., D.A.T., D2 Tests		+	Exp 90; Control 90. Positive findings.
Christiaen and Verhofstadt-Denève	1976	Belgium	P	B	B	37	ANOVAS		–	Exp 20; Control 17. There were no significant findings.
Gaudreau	1992	USA	P	B	M	437	Standardised Tests		–	3 group design. No significant differences in standardised tests.
Liptrap	1998	USA	P	B	B	571	TASS Tests		+	The chess group (67) outperformed the non-chess group (504) by 4.3 TLI on TAAS reading (0.01) and 6.4 TLI on TAAS maths (0.00001) over two years.

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
Eberhard	2003	USA	B	B	M	137	T-Tests		–	Grade 7/8 students. Chess group 60, control 77. There was no significant improvement on quantitative CogAT tests for Chess, non-chess, economically advantaged, or disadvantaged students.
Gobet and Campitelli	2006	England				N/A		✓		
Hong and Bart	2006	Korea	P	B	B	38	KBST RPM TONI-3 ANOVA		–	Chess group 18, control group 20. There were no significant improvements in maths or reading scores.
Yap	2006	USA	P	B	B	321	RIT scores ANOVA Multiple Regressions		+	Chess group 233; control 88; from 17 schools. R.I.T. maths significantly improved for the chess group in all three years and for reading in one year.
Scholz et al.	2008	Germany	P	B	M	53	ANOVAS		+	Chess group 31; Control 22 randomly selected—a clear advantage for the chess group concerning improvement of basic mathematics skills.
Garcia	**2008**	**USA**	**P**	**B**	**B**	**54**	**ANCOVAS**		–	Chess group 27; Control 27. There was no statistically significant improvement for the chess group in either reading or maths.
D' Eredità and Ferro	**2010**	**Italy**	**H**	**B**	**M**	**45**	**Straight comparisons**		–	Chess group 10; Control group 35. Questions constructed according to the PISA framework. There were no significant findings due to unexpectedly poor numbers.
Barrett and Fish	**2011**	**USA**	**B**	**B**	**M**	**31**	**TAKS tests ANCOVA**		+	Chess group 15; Control group 16. Significant relationship between chess group and probability, statistics, numbers, operations and quantitative reasoning.

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
D' Eredità	2012	Italy	P	B	M	30	INVALSI		_	Chess group 15; control group 15 for pretest, 50 for posttest. There were no significant findings, and the researcher described his statistics as 'poor.'
Trinchero	2012	Italy					Multiple Studies			Summary of studies in Italy since 2005: 2005/6 = 290; 2006/7 = 166; 2007/8 = 22; 2009/10 = 813; 2010/11 = 142; 2010/11 = approx 2000 (see Boruch and Romano, 2011)
Kovacic	2012	Argentina	P	B	M	82	T Tests		+	Chess group 43; Control group 39. Significant findings in favour of the chess group in maths tests.
Kazemi et al.	2012	Iran	B	B	M	180	T Tests		_	Metacognition
Martinez	2012	USA	P	B	B	701	Standardised Tests ANOVA MANOVA		_	701 participants over three years: Gr 3 220; Gr 4 234; Gr 5 247. Total 701. Chess only 29; Music only 246; Both 38; Neither 388. No significant results.
Trinchero	2013	Italy	P	B	M	568	ANOVA		+	Chess Group with pretest 380; Control Group with pretest 115; Chess Group without pretest 32; Control Group without pretest 41. Chess training C.A.T. assisted. Clear improvement in maths scores results in favour of the chess group.
Bart	2014	USA				N/A		✓		
Gliga and Flesner	2014	Romania	P	B	M	38	S.P.T. Maths, ANOVA		+	Chess Group 20; Control Group 18. Chess group significantly improved school performance in maths.
Trinchero et al.	2014	Italy	P	B	M	1057	OECD-PISA maths ANOVA		+	Chess group school teacher 221; Chess Group chess instructor 402; Control Group 434 randomly selected. A clear advantage in maths scores for the chess instructor group. Habits of Mind was a factor.

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
Khosroroad et al.	2014	Iran	P	B	M	20	Key Maths Test T-Tests		+	Chess group 10; Control group 10 randomly assigned. Significant results in favour of the chess group.
Nicotera and Stuit	2014	England				N/A		✓		
Rezvani and Fadaee	2014	Iran	P	B	M	66	Paired T-Tests		+	Chess Group 25 and Control Group 41 were randomly assigned. Significant result for the chess group v control group.
Rajotte and Voyer	2014	Canada	P	B	M	151	ANCOVA		+	Chess Group 67; Control Group 84. Significant result in favour of the chess group.
Achig	2015	Ecuador	P	B	M	35	T-Tests		+	Chess group 15; Control group 20. Significant result in favour of the chess group.
Sala et al.	2015	Italy	P	B	M	560	OECD-PISA T-Tests Linear Modelling		+	Chess Group 309; Control Group 251. The chess group scored significantly higher than the control group on mathematical problem-solving.
Zeynalli	2015	Azerbaijan	P	B	B	227	T-Tests		+	Grade 2-4: Chess Group 140; Control Group 87. (Grade 1-3 chess group 114). There were positive tests for chess groups for maths and reading in some years (mixed results).
Gates	2015	USA				N/A		✓		
Aydin	2015	Turkey	H	B	M	26	Wilcoxon Test Mean and Standard Deviation		+	Chess Group 14; Control Group 12. Visually Impaired students. There was a statistically significant result for the chess students in one of the two semesters measured.
Trinchero and Sala	2016	Italy	P	B	M	931	Multilevel Linear Modelling OECD-PISA		+	Chess group chess instructor teaching heuristics for transfer 320; Chess group school teacher 220; Control group 391. The group taught heuristics promoting transfer and scored significant improvements in maths scores, while the other groups did not.

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
Işıkgöz	**2016**	**Turkey**	**B**	**B**	**M**	**274**	**T-Tests ANOVA**		+	Chess group 137; Randomly selected control group 137. Statistically significant end-of-year results in favour of the chess group were found.
Dapica-Tejada	**2016**	**Spain**	**P**	**B**	**R**	**60**	**PROLEC-SE Reading Test**		–	Chess Group 30; Control Group 30. The chess group had a weak positive but not significant reading result.
Joseph et al.	**2016**	**India**	**P**	**B/I**	**B**	**100**	**T-Tests**		+	Chess group 48; Randomised control group 52. There was a significant result for the chess group versus the control group in maths and reading.
Burgoyne at al.	2016	England				N/A		✓		
Sala & Gobet	2016	England				N/A		✓		
Sala et al.	2016	Italy	P	B	M	52	ANCOVA		–	Students were randomly assigned to a Chess group, a Go group and a Normal class group. The numbers in each group needed to be supplied. Apart from a small result in favour of the chess group v Go in maths, there were no significant results.
Burján	2017	Hungary	H	B-A	M	79	Standardised Tests		+	Chess group 20; Control Group A 37; Control Group B 22. Statistically significant results in maths scores for the chess group versus two control groups selected from comparable local schools.
Rosholm et al.	2017	Denmark	P	B	M	482	Standardised Tests		+	Chess group 323; Control group 159. Year-3 students. Significant result in favour of the group that received a chess lesson instead of a maths lesson each week for 3/4 of a year.
Expósito Barrios	2017	Spain				N/A		✓		

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
Jerrim et al.	2018	England	P	B	B	4009	Standardised Tests		–	There was no statistically significant result for maths or reading scores. This randomised test has been regarded as a benchmark for researching children learning chess and cognitive skills with statistical rigour.
Nor Aishah	2018	Malaysia	P	B	M	76	T-Tests School mathematics and CCTST Critical Thinking		+	School students from two schools average age 10. Chess group 34; Control 42. Significant results for maths and critical thinking in one of the two schools.
Voyer et al.	2018	Canada	P	B	M	185	ANOVA		+	Chess group 87; Control group 98. Age 8-9 years. The chess group scored higher on the maths test.
Poston and Vandenkieboom	2019	USA	P	B-A	B	854	ANOVA Standardised Tests SBA MAP NWEA		+	139 participated in chess club (77 of whom played in a USCF-rated event); 715 did not play chess. Those who played USCF events had highly significant results for maths and reading. The authors noted: 'Various comparisons showed a Math score increase more than six times the standard deviation of the results.'
Islam et al.	2019	Bangladesh	P	B	M	569	Standardised Tests P.S.C.		–	Children of average age of 10 from 16 schools in Bangladesh. 281 were randomly chosen for chess and 288 for control. There is no significant finding for maths scores.
Meloni and Fanari	2019	Italy	P	B	M	85	MANOVA SPM and AMOS		–	Children 9 years old. Chess Group 48; Control Group 37. There were no positive findings regarding cognitive skills or metacognition. However, encouraging findings for 'ability to create a mental representation,' 'categorisation', and 'self-assessment.'
Ortiz-Pulido et al.	2019	Mexico				N/A		✓		
Arraez Infantes	2019	Spain				N/A		✓		

Authors	Year	Country of Origin	School Level (S) H=High; P=Primary B=Both	Chess Playing Level (C) B=Beginner I=Intermediate A=Advanced	Intervention (I) M=Maths; R=Reading; B=Both (B); O=Other	Participants (P)	Testing Methodology (T)	Meta-Analysis	Direction of Findings	Notes/Key Findings
Mahmudov et al.	2020	Indonesia	P	B	M	125	Regressions		+	Grade 2 students Chess group 80 strong positive relationship between chess and mathematics.
Garate-Quispe et al.	2021	Peru	H	B-A	M	95	GLM RLM Mann-Whitney		+	Children age 12. Chess group 43, Control group 52. Positive results in respect of mathematical logical reasoning, attention and concentration. Improvements in chess Elo rating for the chess group was a factor.
Brito	2021	Ecuador				N/A		✓		
Blanch	2022	Spain				N/A		✓		
Gobet and Sala	2022	England				N/A	Cognitive Training: A field in search of a phenomenon			Far Transfer does not Exist
Tachie and Ramathe	2022	South Africa	H	I	M	51	SA-SAMS test		+	Chess group 25; Control group 26. Grade 9 students 15-16 years old from 7 high schools. Chess group outperformed control group in the group test as well as the S.A.-

The results reveal a growing body of research spanning nearly five decades (1974–2022) and conducted across 25 countries. The frequency of publications has steadily increased, with most studies published after 2010. Most studies (69%) exclusively measured numeracy outcomes, while fewer examined literacy alone (4%) or both numeracy and literacy simultaneously (27%; see Figure 2, Chart 2). Notably, the sample populations predominantly consisted of primary school children learning to play chess, often with relatively short intervention durations, typically lasting from several weeks to less than two years (Figure 2, Charts 1 and 3).

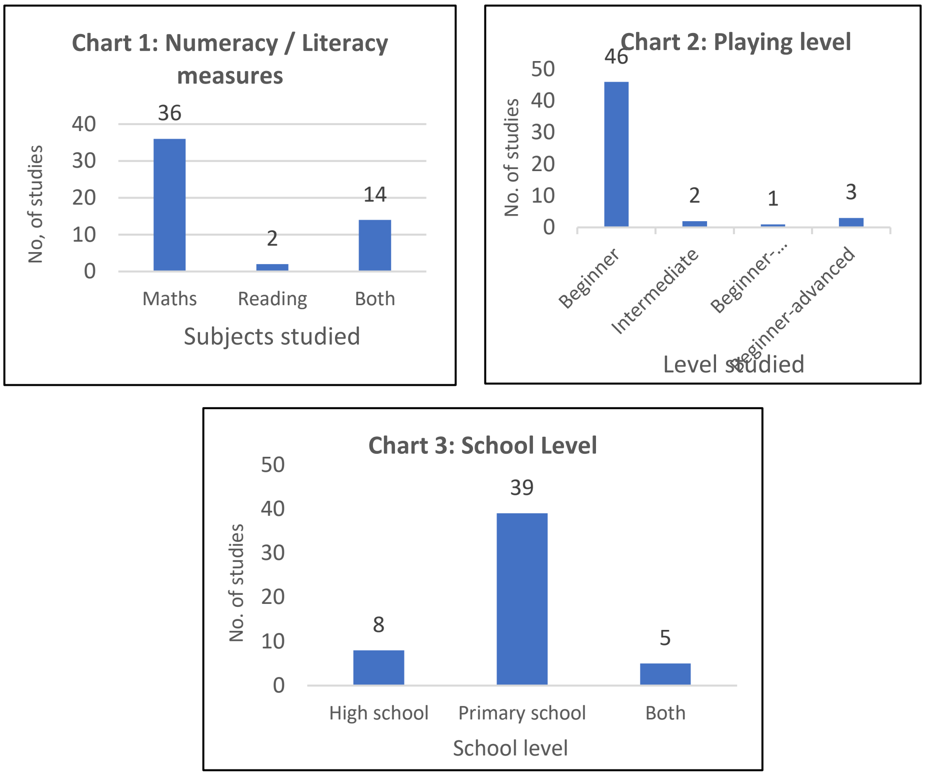


Figure 2: Number of studies

3.11.4 Discussion

Most studies included in this review (approximately two-thirds) report positive associations between chess instruction and numeracy or literacy outcomes. However, methodological rigour varied significantly, and many positive findings emerged from studies with substantial methodological shortcomings, including small sample sizes, inadequate or absent control groups, unclear randomisation procedures, and limited longitudinal assessment.

Only twelve studies featured samples exceeding 500 participants, and of these, three (Martinez 2012, Jerrim et al. 2018 and Islam et al. 2021) reported no significant academic benefits from chess instruction. Of these three, the randomised controlled trial by Jerrim et al. (2018), involving 4,009 participants, stands out for its methodological robustness and its null findings regarding improvements in numeracy, literacy, and science scores. These outcomes align with reviews by Sala & Gobet (2017a, 2017b, 2022), who critically question the existence of far transfer from chess skills to general academic domains.

However, two randomised studies by Trinchero et al. (2014) and Trinchero and Sala (2016) provided evidence of positive effects under specific conditions, emphasising instructional methods rather than chess playing alone. The comprehensive Castle Project by Trinchero and Robasto (2021) similarly suggested that the pedagogical approach to chess instruction—specifically focusing on metacognitive strategies and structured reflection—may be key to achieving cognitive and academic benefits.

3.11.5 Methodological limitations in the literature

The literature reviewed frequently suffers from four critical methodological limitations:

- *Insufficient Statistical Power:* Most studies reviewed employed small samples (often fewer than 100 participants), limiting the reliability and generalisability of results (Blanch, 2022; Nicotera & Stuit, 2014).

- *Lack of Rigorous Control Conditions:* Many studies lacked appropriate comparison groups or employed passive (‘no-intervention’) controls, making it challenging to attribute observed benefits specifically to chess instruction (Sala & Gobet, 2017a).

- *Short-Term and Immediate Measurement:* Most studies measured immediate or short-term outcomes, typically neglecting longer-term effects on academic performance.

- *Inconsistent Outcome Measurement:* The variability in outcome measures (e.g., standardised versus non-standardised tests, immediate versus delayed assessment) further complicates direct comparison across studies.

Given these limitations, it remains difficult to draw definitive conclusions about the causal effects of chess instruction on children's numeracy and literacy outcomes.

3.11.6 Critical Research Gaps

Three key gaps emerged clearly from this review, which in turn motivate future research directions:

1. **Chess Skill Level and Intensity:** Few studies (only six identified: Van Zyl, 1991; Joseph et al., 2016; Burjan, 2016; Poston & Vandenkieboom, 2019; Garate-Quispe, 2021; Tachie & Ramathe, 2022) specifically investigated the academic effects of advanced chess practice or competitive play beyond beginner-level instruction. Notably, Poston and Vandenkieboom (2019) reported substantial gains in numeracy and literacy outcomes associated with sustained competitive chess participation, highlighting a promising yet underexplored research avenue.

2. **Longitudinal Effects:** The existing literature largely neglects the long-term academic impacts of sustained chess engagement. Longitudinal studies are urgently needed to assess potential cumulative educational benefits.

3. **Conceptual and Methodological Clarity:** Clarifying precisely which aspects of chess instruction (e.g., competitive play, reflective practice through move analysis, structured instruction methods) might contribute to academic improvement remains inadequately explored. Additionally, clear theoretical frameworks (e.g., deliberate practice, metacognition, scaffolding, motivation, habit formation) have yet to be systematically tested in the context of chess education research.

3.11.7 Directions for Future Research

Given these identified gaps and limitations, future research should prioritise the following:

Advanced Chess Engagement: Studies should heed Sala & Gobet's conclusion and move beyond research focused on students leaning to play chess. Specifically, they should instead examine sustained chess practice and competitive participation over time, utilising objective measures such as internationally recognised chess ratings to classify participant skill levels.

Rigorous Longitudinal Designs: Research should employ longitudinal designs to identify potential delayed or cumulative academic benefits.

Enhanced Methodological Rigour: Future studies should adhere to rigorous experimental designs, including large sample sizes, random allocation with active and passive control groups, clearly defined intervention protocols, and transparent outcome measures.

By addressing these research gaps with rigorously designed studies, researchers can provide conclusive evidence regarding the potential of chess instruction to enhance children's educational outcomes, ultimately informing policy decisions and educational practices more effectively.

This scoping review has assessed the existing empirical literature investigating the educational benefits of chess instruction on children's numeracy and literacy outcomes. Despite widespread belief in the academic advantages of chess, the current evidence is fragmented, methodologically inconsistent, and often limited by issues such as inadequate sample sizes, absence of appropriate control conditions, and insufficient longitudinal assessment. Most reviewed studies focused narrowly on short-term interventions among beginner-level primary school students, with few rigorously designed studies available to conclusively support or reject the claim of general cognitive transfer to academic skills.

However, several significant research gaps were identified. Notably, very few studies have examined whether sustained chess practice or competitive play at intermediate to advanced skill levels might confer lasting academic benefits. The promising findings reported by Poston and Vandenkieboom (2019), who linked competitive chess engagement to substantial gains in mathematics and reading outcomes, highlight the need for further rigorous, longitudinal research in this area.

To decisively address these gaps, future studies should prioritise methodological rigour, including adequately powered randomised controlled trials featuring clear intervention protocols, active and passive control groups, and robust longitudinal follow-ups. Additionally, future investigations should explicitly examine the mechanisms through which chess practice might facilitate academic improvements, focusing on reflective practices such as structured move analysis, deliberate practice methodologies, and competitive tournament participation. Motivated by the findings of this scoping review, an example future research line of enquiry is illustrated in Figure 3.

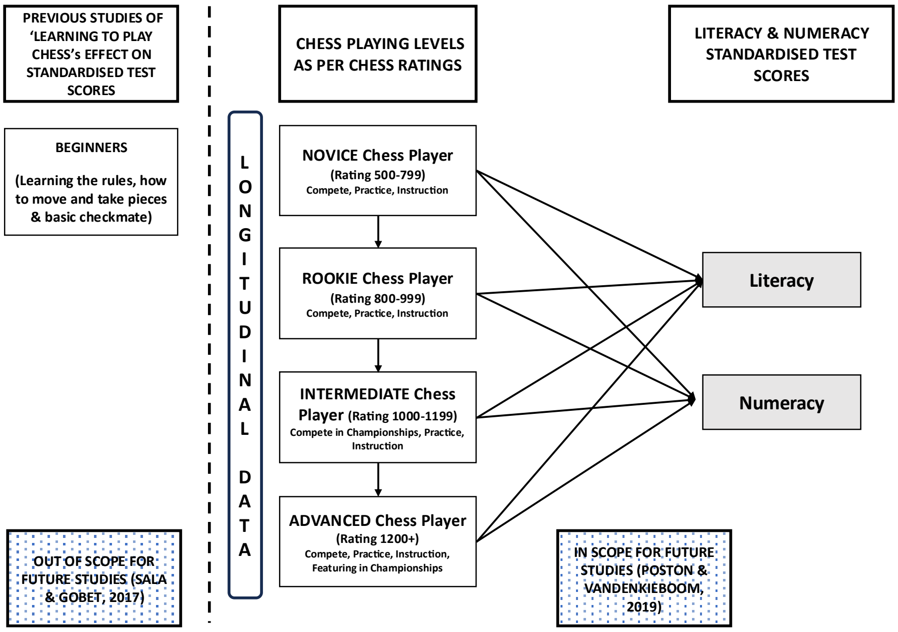


Figure 3: Framework for future research on effect of practising and competing in chess on standardised literacy and numeracy test scores

In conclusion, while existing evidence does not conclusively demonstrate academic benefits of chess instruction for literacy and numeracy outcomes, significant opportunities remain for well-designed future research. Such research has the potential not only to clarify the educational value of chess instruction but also to inform more effective integration of chess into educational curricula worldwide.

Note: There were 27 studies that did not meet the selection criteria for the scoping review but need to be noted (see Appendix B).

3.12 Summary and Implications

Since Sala and Gobet (2017a) declared that, "rather than searching for a way to improve overall domain-general cognitive ability, the field should focus on clarifying the domain-specific cognitive correlates underpinning expert performance", researchers appear to have complied progressively (especially since the COVID-19 era). They appear to be more interested in chess, computers, AI and a myriad of other possibilities that are not directly related to thinking skills.

The literature review has identified a small but interesting window for research. Although the Poston and Vandenkieboom (2019) study was in only one school, the findings were so strong that they warrant further investigation. The existing, accessible data from the QCAA and the QJRL present an excellent research opportunity to close an identified gap in existing knowledge.

The scoping review uncovered a large body of literature relating to children learning chess and possible resulting benefits for their literacy and numeracy scores. It provides further evidence to justify a study into whether “far transfer” may exist. It was preceded by a systematic literature review of all studies found in the field of children learning chess other than those related to literacy and numeracy. The scoping review and the preceding systematic literature review provided a comprehensive overview of empirical chess research, primarily involving chess and children.

3.13 Conclusion

3.13.1 Conclusions from the Systematic Literature Review and the Scoping Review

Whoever was involved in inventing chess over 1500 years ago produced an extraordinary game, where the movement of the pieces allowed by the rules of the game produces an exceptional challenge to participants to try to get as close to mastering the game as they can. Calculating the possible number of moves in a chess game has not been possible. However, in 1950, mathematician Claude Shannon concluded that there are approximately 10^{120} possible games in chess. It is possible to say that no human can ever completely master the game. However, the complexity of chess lends itself to research related to how the human mind works and to a range of perceived benefits.

For many years, researchers have been fascinated by the idea that learning chess can benefit society. When walking into a chess tournament hall, it is obvious to the onlooker that groups of people are in deep thought (even at the most basic junior level). It is easy to see that young players are concentrating with their heads between their hands. They are trying to find a way to win. In each position, they are trying to solve a problem. As they get older and improve, they may become better at memorising things they have learned, such as chess opening theory. They may also become better at planning a sequence of moves.

One of the certainties of attending an open chess tournament is that it represents a cross-section of society. It is not unusual to see a barrister playing a labourer or an eight-year-old playing an international master. We then hear that a blind chess player, or a person with quadriplegia, has won a chess tournament. The list goes on.

Worldwide, there is a growing number of inter-school chess competitions where educators can easily see some of the obvious benefits for children in playing chess, not least the good manners in shaking hands before and after the game, concentration, and winning and losing with dignity. However, a significant number of researchers, many of whom are schoolteachers, are highly motivated by their observations to conduct research to confirm or otherwise what they believe they have observed regarding educational benefits.

The systematic literature review and the scoping review endeavoured to inform interested parties comprehensively about the current state of play in chess research. This is an important contribution as it may save some researchers valuable time or inspire others to conduct research. It also helps to provide more cohesion in research efforts. Further, it may encourage schools to include chess in their offerings.

It should be noted that, when selecting studies for the systematic literature review, several studies were omitted as they did not directly relate to mathematics or reading scores as required by the review. These 27 studies from 13 countries, which included cognitive skills in their outcome measures, are shown in a table in Appendix B, and include Critical Thinking, Creative Thinking, Science Scores, IQ, Reasoning, Problem Solving, Spatial Ability, Planning, Concentration, Working Memory and Analytical Thinking.

Can we be sure that learning chess leads to all sorts of benefits? What are those possible benefits? In these investigations, the researcher has been surprised at the sheer extent of research in the field. The systematic literature review involved 393 papers allocated to 92 terms and eight categories. The scoping review included 54 papers relating to numeracy and literacy and 10 literature reviews.

The researcher aimed to uncover all the research relating to the possible benefits of children learning chess and to present it in an easy-to-understand way. This should make it easier for would-be researchers to choose a useful topic.

The range of terms (92) was surprising. It is not hard to think of 10-20 thinking skills that might be possible in chess-play, but the overall diversity was not foreseen.

There is little doubt that the most important research has been theories relating to how the human mind works. A continuous chain of researchers from de Groot in the early 1940s, linked with Chase and Simon in the 1970s to the 1990s, and to Gobet and his colleagues in the present day has investigated this topic. Simon and Newell (1971), Chase and Simon (1973), Simon (1983), Simon (1986), Simon and Chase (1988), Gobet and Simon (1996, 1996a, 1996b, 1998a, 1998b). Gobet and Simon were involved in chunking and template theory. The CHREST computer model of cognitive architecture, developed by Gobet and colleagues over 20 years ago, plays an important part in research on how the human mind works.

Many papers focus on "far transfer", the idea that ideas learned in one field (e.g., learning chess) can be transferred to another unrelated field (e.g., better scores in maths tests). Currently, this is looking highly unlikely. The number of cognitive processes and key thinking skills that the research covers (47) is surprisingly high.

Interestingly, several studies in the field of psychological and emotional wellbeing have used chess as a tool (e.g., autism, mental imagery, mental wellbeing, risk aversion, self-efficacy). A promising field of chess research involves children with special needs, difficulties, disabilities or disadvantages.

One of the most hotly debated topics is gender in chess. Why are men better than women? The answer is that they probably are not, but researchers are not certain.

In conclusion, it is noted that: a) a smorgasbord of opportunities awaits current or would-be researchers; and b) methodological weaknesses and a general lack of rigour are present to some extent in over 90% of studies (e.g., small sample size, no randomisation, no control groups). Some researchers – e.g., Blanch (2022), Sala and Gobet (2016), and Jerrim et al. (2016) – hold everyone to account.

Future researchers should think carefully about their study design and the feasibility of conducting “the ideal design” as proposed by Gobet and Campitelli (2006):

> *This design includes the following requirements in addition to a treatment group: pretest and posttest; two control groups (a do-nothing group and an active control group, necessary for removing the possibility of a placebo effect); random allocation to each group; different personnel for conducting the pretest, the treatment, and the posttest; and ideally – but nearly impossible to do in practice – experimenters' and testers' unawareness of the nature of the assignment into groups, and participants' unawareness of the goal of the experiment and the fact that they take part in an experiment.*

Apart from providing readers with a comprehensive picture of research in the world of children learning chess, the literature review has pointed the way to the next steps in this study. The findings of Gobet and Sala (2016, 2017a, 2017b, 2017c, 2018) that “far transfer” almost certainly does not exist, and the paper by Poston and Vandenkieboom (2019) positing that it likely does exist, motivated the design of this study, which follows here.

3.13.2 Conceptual Model of the Study

Based on the scoping review, a conceptual model was developed illustrating a new direction in investigating the possible relationship between practising and competing in chess (represented by chess ratings) and the dependent variables of literacy and numeracy standardised test scores in Queensland.

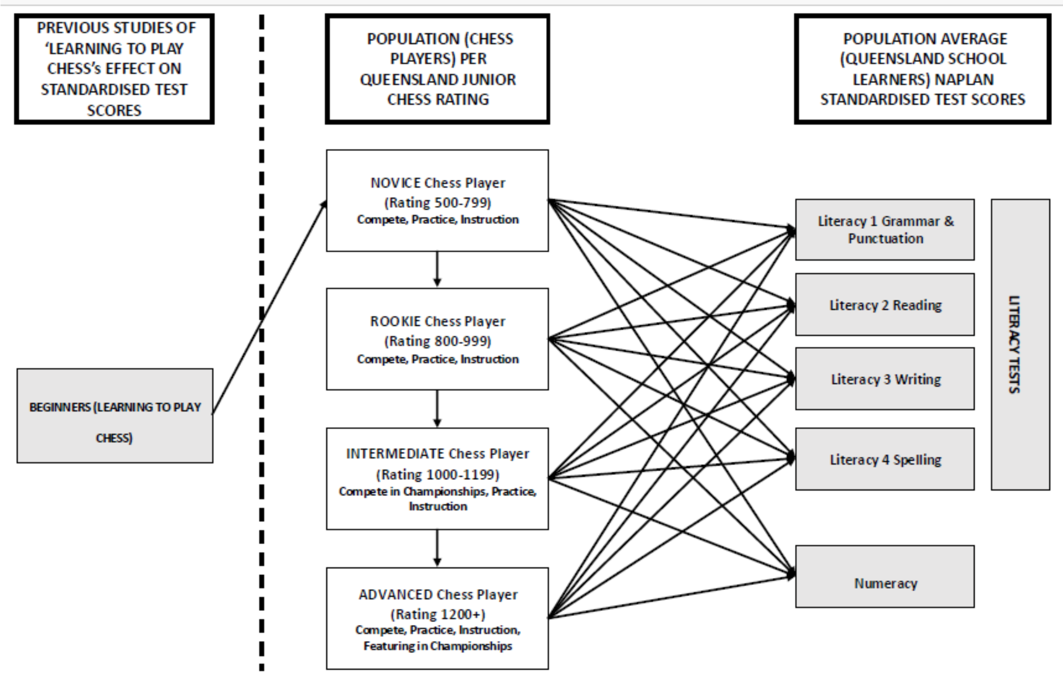


Figure 4: Conceptual model guiding the study

This study is concerned with 10 independent variables of interest and their possible relationships. These are:

Independent variables: Chess player ratings groups (4) (Novice, Rookie, Intermediate, Advanced) Rating_Max_Group, plus categorical variables, including School_Group, School_Type_Group, Gender_Group, LBOTE_Group and Year_Level.

This study is concerned with 10 dependent variables of interest and their possible relationships. These are:

SCALE_SCORE_Y (5) measuring chess rated students' 5 own NAPLAN test scores, and

Diff_NAPLAN_Y (5) measuring the state average scores per 5 NAPLAN test scores.

3.13.3 Research Questions and Hypotheses

The overarching research question of the study is "Does playing chess as measured by extra practice and competing by Queensland school students have measurable educational benefit in terms of standardised literacy and numeracy test scores?".

RQ1: Is there a statistically significant difference between Queensland chess ratings groups and students' own NAPLAN scale scores?

$H1_0$: Chess ratings groups do not significantly differ from students' own NAPLAN test results in:

a) Scale Score - GP
b) Scale Score - NMCY
c) Scale Score - READ
d) Scale Score - SPEL
e) Scale Score - WRIT

RQ2: Is there a statistically significant difference between Queensland chess rated players in school groups as defined by the density of rated chess players per school and the students' own NAPLAN scale scores?

$H2_0$: Chess rated players in school groups do not significantly differ from students' own NAPLAN test results in:

a) Scale Score - GP
b) Scale Score - NMCY
c) Scale Score - READ
d) Scale Score - SPEL
e) Scale Score - WRIT

RQ3: Is there a statistically significant difference between Queensland chess rated players' in school types and the students' own NAPLAN scale scores?

$H3_0$: Chess rated players in school types do not significantly differ from students' own NAPLAN test results in:

a) Scale Score - GP
b) Scale Score - NMCY
c) Scale Score - READ
d) Scale Score - SPEL

e) Scale Score - WRIT

RQ4: Is there a statistically significant difference between Queensland chess rated players in home language other than English groups and the students' own NAPLAN scale scores?

$H4_0$: Chess rated players in LBOTE groups do not significantly differ from students' own NAPLAN test results in:

a) Scale Score - GP
b) Scale Score - NMCY
c) Scale Score - READ
d) Scale Score - SPEL
e) Scale Score - WRIT

RQ5: Is there a statistically significant difference between Queensland chess rated players in gender groups and the students' own NAPLAN scale scores?

$H5_0$ Chess rated players in gender groups do not significantly differ from students' own NAPLAN test results in:

a) Scale Score - GP
b) Scale Score - NMCY
c) Scale Score - READ
d) Scale Score - SPEL
e) Scale Score - WRIT

RQ6: Is there a statistically significant difference between Queensland chess rated players in school year level groups and the students' own NAPLAN scale scores?

$H6_0$ Chess rated players in school year level groups do not significantly differ from students' own NAPLAN test results in:

f) Scale Score - GP
g) Scale Score - NMCY
h) Scale Score - READ

i) Scale Score - SPEL
j) Scale Score - WRIT

as measured by students' own results in NAPLAN testing.

RQ7: Is there a statistically significant difference between Queensland chess rating groups and the state average NAPLAN scores?

$H7_0$: Chess rating groups and school groups do not statistically differ from the Queensland state average NAPLAN test scores in:

a) Diff NAPLAN Score - GP
b) Diff NAPLAN Score - NMCY
c) Diff NAPLAN Score - READ
d) Diff NAPLAN Score - SPEL
e) Diff NAPLAN Score – WRIT

3.13.4 Conclusion

This chapter presented the outcome of a systematic literature review and a scoping review in order: a) to capture the extent and content of chess research as it relates to the benefits of playing chess; and b) to identify chess studies relevant to learning, practising and competing in chess and its relationship with standardised literacy and numeracy test scores. The chapter culminated in identifying gaps in the literature and a new line of enquiry as defined by the study's conceptual model, research questions and hypotheses. Chapter Four presents the methodology adopted to answer these research questions.

CHAPTER 4: METHODOLOGY

4.1 Introduction

Chapter Two presented: a) a broad systematic literature review related to chess research generally; and b) a scoping literature review focused on the study's purpose and aims. The chapter concluded by presenting a conceptual model and the research questions guiding this study.

The review of the literature in Chapter Three related to the parent discipline of education, and specifically to the possible association between learning, practising and competing in chess and its possible effect on standardised test scores (especially numeracy and literacy) amongst school children.

The review revealed several lines of enquiry that are extensively covered more broadly, such as the effects on thinking, and on social and personal development skills. However, although they are often referred to in the literature as important concepts, the research investigating the effect of practising and competing in chess on standardised numeracy and literacy test scores remains limited. The study aimed to determine whether a statistically significant relationship exists between students practising and competing in chess and their standardised literacy and numeracy test scores. This further indicates if far transfer of skills learned in chess to academic scores occurs.

This chapter details the research methodology adopted for the study, its purpose, and how it was designed and implemented. It addresses how the research questions were approached, the paradigm adopted by the study, the research design, and the methods and analysis techniques. At the outset, determining the research paradigm served as a framework for the methodology.

4.2 Research Paradigm

Making a paradigmatic knowledge claim involves the researcher establishing foundational assumptions about ontology, epistemology and methodology at the outset of their inquiry (Creswell, 2009). Philosophical discussions frequently focus on defining knowledge and how it can be understood. This study employed a pragmatic approach rooted in post-positivism to enrich critical and interpretivist research. It aligns with post-positivist principles, arguing such an approach is essential for meaningful social science investigations.

Positivism faces criticism for its deterministic perspective on causal relationships, often reducing human behaviour to statistical models that fail to capture the complexity of human nature and experiences (Neuman, 2006). Despite growing critiques and the rise of alternative paradigms, positivism and related frameworks continue to play a significant role in contemporary research.

Building on the ideas presented by Inayatullah (1998, 2002), it is argued that meaningful analysis of social issues or critique of existing frameworks requires an understanding of objective and value-free observations of empirical phenomena. This study proposes that establishing an empirically validated connection between practising and competing in chess and standardised numeracy and literacy test scores can be a solid foundation for future research. Specifically, this exploration would focus on critical and interpretivist approaches within social sciences. The study operates under the principle that positivist research enhances meaningful critical and interpretivist methods in education studies. However, a key limitation of this approach is the acknowledgement that absolute causality cannot be definitively established.

The study is necessarily an explanatory study that responds empirically to the research questions. This suggests a positivist paradigm or lens to observe the phenomenon. However, as per previous studies, and owing to the ambiguity of the topic, establishing “absolute truth” in the findings cannot be ascertained. Therefore, a post-positivist paradigm is more suited to the methodological approach.

While Neuman (2006) equates post-positivism with positivism, Creswell (2009) argues that post-positivism challenges the conventional positivist idea of absolute truth in knowledge. This perspective acknowledges that researchers cannot be entirely sure about their knowledge claims when studying human behaviour. According to Phillips and Burbules (2000), as cited in Creswell (2009), post-positivism emphasises that social science research should consider causes as likely influencing outcomes rather than asserting definitive causation.

Post-positivism is built on the careful observation and measurement of behaviours reflecting broader social realities, requiring laws and theories to undergo testing and refinement to enhance understanding (Creswell, 2009). Key post-positivist assumptions include: (a) knowledge is based on conjecture and absolute truth is unattainable; (b) research aims to test, refine or reject theoretical claims; (c) evidence, data and rational interpretations underpin knowledge; (d) the focus of research is on uncovering factual statements to address issues and describe causal relationships; and (e) objectivity is essential in identifying factual statements while minimising bias (Creswell, 2009, pp. 7–8).

This study aligns with post-positivist principles, recognising that empirical research enriches critical and interpretivist approaches. As social sciences and the study of individual learning evolve, one cannot claim absolute truths but can provide probable insights based on empirical observations and measurements. By adopting a quantitative research approach (Creswell, 2009; Neuman, 2006; Perry, 2008), this study establishes a foundation for further critical and interpretivist research into the complex nature of reality. The post-positivist paradigm appropriately supports the analysis of probable causal relationships, ensuring an objective approach to the research process.

4.3 Research Design and Methodology

The study examines the relationship between students' standardised numeracy and literacy test scores on their various Australian National Assessment Program – Literacy and Numeracy (NAPLAN) tests from Years Three, Five, Seven and Nine (seven years) and their chess rating scores over the same period.

Suppose the research problem identifies variables (chess ratings) that are seen to have an influence on dependent variables or to provide a greater understanding of the outcome (test scores). A quantitative approach is most fitting (Creswell, 2009). This also allows the explanation of the relationships inherent in the problem. The problem statement and the conceptual framework of this study presented in Chapter Three indicated inherent relationships between the variables of interest, thus illustrating a fit with a quantitative approach.

Neuman (2006) explains that a quantitative research design is appropriate when concepts are defined as distinct variables and hypotheses are based on causal models. Quantitative methods often address explanatory questions (Creswell, 2009) and align with the post-positivist paradigm discussed above.

This study is therefore conducted as a quantitative longitudinal research project, focusing on observations made over points in time (Neuman, 2006) as determined across seven school years (Years Three, Five, Seven and Nine) and the associated chess player ratings at those points in time using quantitative techniques.

4.3.1 Conceptualisation and Operationalisation of Variables

The measurement development process in this study involves both the conceptualisation and the operationalisation of the key concepts to allow their empirical observation (Neuman, 2006). Conceptual definitions of the study's variables, which were explained in Chapter Two, formed the foundation for their operationalisation in terms of previously validated scales that: 1) measure school children's numeracy and literacy scores in Queensland (NAPLAN standardised test scores); and 2) measure chess players' playing strength according to an internationally validated rating scale (QJRL chess ratings).

Conceptualisation is formulating systematic and precise conceptual definitions from abstract ideas (Neuman, 2006). To ensure clarity, conceptual definitions linked to the study's conceptual framework were adopted, minimising ambiguity. A conceptual definition explicitly explains a concept (Neuman, 2006).

While the standardised NAPLAN test scores for numeracy and literacy (spelling, writing, reading, grammar and punctuation) are well described and validated, the study relies on the chess ratings to represent players' playing strength categories.

A key premise of the study is that chess ratings reflect chess players' practising and competing in chess-rated games. Both these concepts are implicit in gaining a chess rating. The study conceptualises "practising" as preparing for competition and reflecting on previous games as noted while playing and discussing the moves thereafter. The study conceptualises "competing" as recorded participation in rated competitions and winning, losing or drawing with other rated players. Practising and competing occur only after a student has learned to play the game as a “beginner”. Once they have learned to play, they can practise and compete for a chess rating.

Operationalisation: The study relies on secondary data derived from validated measures of numeracy and literacy in Queensland schools across Years Three, Five, Seven and Nine. As mentioned, these are the NAPLAN standardised test scores. The test covers four main areas: reading, writing, language conventions (spelling, grammar, punctuation) and numeracy. NAPLAN tests are designed to be valid and reliable, ensuring they accurately measure literacy and numeracy skills while providing consistent results. The development process involves collaboration with education, assessment and curriculum experts to create questions that align with national standards.

To ensure validity, NAPLAN tests undergo rigorous trials to confirm that the questions effectively assess the intended skills. Reliability is maintained through tailored test designs that adapt to a student’s performance level for more precise measurement (see https://myschool.edu.au/media/1821/reliability-and-validity-of-naplan-factsheet.pdf).

The Queensland chess rating scale, particularly for junior players, is based on the Queensland Junior Rating List (QJRL). This system uses a variation of the Elo rating system, which calculates ratings based on a player’s tournament performance. The rating scale is primarily based on the Elo rating measurement adopted by the World Chess Federation (FIDE). The Elo chess rating system is designed to quantify chess players’ skill levels based on their game performance against other players. It was developed by Arpad Elo, a Hungarian-American physicist and chess player, in the 1960s.

Initial Ratings: Players start with a base rating, which is adjusted as they participate in rated games.

Performance-Based Adjustments: After each tournament, a player’s rating changes depending on their score, their opponents’ ratings and the expected outcomes.

Expected Score Formula: The system calculates the expected score based on the rating difference between players. This formula is derived from the Elo system and helps determine how much a player’s rating should change after a game.

The QJRL ratings are updated six times a year and are tailored to reflect the playing strength of junior players in Queensland. This system also incorporates school and club chess games, ensuring a comprehensive rating.

4.3.2 Data Requirements

As noted above, the study relies on secondary longitudinal data from two independent sources: the QJRL; and the Queensland state NAPLAN test scores.

The QJRL data serve to provide the following data about the students with Queensland chess ratings: i) demographic information; ii) chess ratings over the time that they participated in NAPLAN tests; iii) NAPLAN test results for their participation in Years Three, Five, Seven and Nine as applicable. These data provide measures for QJRL-identified students who consented to provide these data. The variables to which the data apply include:

Independent variables:

a) School chess players' maximum chess ratings over a period of seven years (ratingmax_group),
b) School chess players' gender (GENDER_GROUP),
c) The type of school b) school chess players attend (SCHOOL_TYPE),
d) The school group as defined by chess playing density as a proportion of the total n = responses (SCHOOL_ GROUP),
e) Whether school chess players are students with a home language other than English (LBOTE_GROUP)

Dependent variables:

f) The difference between the student's NAPLAN scores and the state average NAPLAN scores (diff_NAPLAN_Y), with Y being the different scale scores for Grammar and Punctuation; Numeracy; Reading; Spelling; and Writing.

g)School chess players' NAPLAN scores per year they participated in the tests (SCALE_SCORE_Y), with Y being the different scale scores for Grammar and Punctuation; Numeracy; Reading; Spelling; and Writing.

The NAPLAN data provide the NAPLAN test scores for each student with chess ratings. The data also provided the mean NAPLAN results for the state, school types, LBOTE and Indigenous status.

These data provide measurements of the study's variables – namely, chess ratings per rating group and five NAPLAN scores. The data also provide measures for interaction variables of interest, including gender, LBOTE, school type and Indigenous status.

4.3.3 Data Acquisition

QJRL data. The QJRL ratings database is administered under the auspices of the Chess Association of Queensland. Dr David McKinnon has administered the Queensland Junior Ratings List (QJRL) since its inception in 1993. The publicly available rating list includes student names, schools and ratings. The study accessed the rating lists over the study period (1998-2023) with the administrator's permission. These lists provided the names of students whom the researcher would contact to gain consent for access to the NAPLAN scores.

NAPLAN data. The Queensland Curriculum and Assessment Authority (QCAA) is an independent state governmental agency that curates all NAPLAN data applicable to Queensland schools and students. While some high-level data are available publicly, individual data are protected under privacy laws. This study required access to the individual and school data associated with QJRL-rated Queensland students, and, as such, a multi-step process to acquire the relevant data was required. They were:

1) Gain University of Southern Queensland Human Ethics research approval.
2) Submit a request detailing data requirements to QCAA.
3) Gain QJRL-rated students' consent to include their NAPLAN data.
4) Provide QCAA with individual names, dates of birth and consent.
5) Receive QJRL-rated student NAPLAN data.

Consent was obtained from study participants (a non-random sample of QJRL-rated students) through various methods: a dedicated online website; the Chess Association of Queensland (CAQ) and Gold Coast Chess websites; and informal requests in the Queensland school chess network. The QCAA verified the consents by email before releasing the data.

The cleaned QJRL and NAPLAN data were merged in Excel and uploaded to SPSS Statistics software for analysis.

4.4 Sampling

A non-random purposive sampling approach was adopted. Purposive sampling is a technique in which researchers intentionally select participants, groups or cases that are most relevant or informative for their study. It focuses on selecting participants who have specific characteristics or experiences that align with the purpose of the research. In the case of this study, the participants were schoolchildren who practise and compete in chess in schools in Queensland and who have received chess ratings.

The study population consisted of school students who had been allocated a chess rating in Queensland. The sampling was not randomised. It was purposive in that it aimed to recruit cases from the QJRL ratings list over the study period. Thus students competing in or having competed in school chess competitions that inform QJRL lists were contacted.

The process of gaining consent was manual and consumed significant time. A total sample of 419 consents was received. As part of the process, QCAA needed to confirm every consent by email. QCAA received 261 consents from their email contacts on record. The discrepancy between the original consents of 419 and the QCAA consents of 261 was explained by the closer network ties the researcher had access to. Six of the QCAA consents were invalid per the QJRL rating list owing to the lack of relevant data in the study period. The final sample was n=255, which was deemed adequate for conducting the multivariate analysis techniques adopted by the study methodology.

4.5 Analysis Techniques

As set out in Chapter Three, a conceptual model including four independent variables (Chess ratings bands) and five dependent variables (NAPLAN standardised test scores for numeracy, spelling, reading, writing, and grammar and punctuation) was presented to guide the study. Seven research questions and hypotheses were also posed, including questions associated with interaction variables of chess-rated students with a home language other than English (LBOTE), gender, school type and school group.

Therefore, as informed by the questions and hypotheses, the statistical analysis was necessarily multivariate. Guidance was sought from Hair et al. (2018) concerning: 1) what multivariate techniques would be relevant to answering the research questions and testing the hypotheses; and 2) what assumptions were applicable in being able to apply these techniques. A rigorous statistical analysis approach would comprise a sequence of different analysis techniques. These were descriptive statistical analysis (central tendency, variation and frequencies), correlation analysis (exploring statistically significant relationships between variables and understanding tendencies), Multivariate Analysis of Variance (MANOVA) (conducting significance testing of variance between chess rating groups, and testing hypotheses and, if significant, the extent of the difference) and, finally, one sample T-Test to test the hypotheses.

4.5.1 Data cleaning

Data cleaning and data screening are essential processes in preparing datasets for analysis. They ensure data accuracy, completeness and consistency, which is critical for reliable results (Hair et al., 2018).

Data cleaning focuses on identifying and correcting errors, inconsistencies or inaccuracies in datasets. It involves:

- Removing Duplicate Entries: Eliminating repeated data to avoid distortion in analysis.
- Handling Missing Data: Addressing incomplete records by filling missing values (e.g., with averages or assumptions), excluding them or using statistical methods like imputation.

- Correcting Errors: Fixing typos, formatting issues or invalid entries in the dataset.
- Standardising Data: Ensuring data are uniform in format, units and structure (e.g., standardising date formats or numeric scales).
- Filtering Outliers: Identifying extreme or anomalous values and deciding whether they should be retained or removed based on relevance.

4.5.2 Descriptive statistics

Descriptive statistical analysis serves the primary purpose of summarising, organising and simplifying large data sets meaningfully (Hair et al., 2018). It provides an overview of the key characteristics of the data, helping researchers understand the nature of the data and their distribution and frequencies. In particular, descriptive statistics are used as follows:

- Central Tendency: Measures like mean, median and mode help identify the dataset's 'centre' or average.
- Variation and Spread: Tools like range, variance and standard deviation show how data points differ or spread out.
- Data Visualisation: Graphs, histograms and scatter plots provide visual representation, making interpreting trends easier.
- Foundation for Further Analysis: Descriptive statistics often serve as the groundwork for inferential analysis, guiding hypotheses or deeper statistical testing decisions.

In the case of this study, data screening was essential in evaluating the dataset to identify potential issues and to determine its suitability for analysis. It was essential to: 1) test the assumptions needed for conducting the different analysis techniques, particularly the normal distribution of the data; and 2) understand the underlying structure of the data. In particular, data screening was used in this study to:

- Check Distribution: Assessing the spread and normality of the data.
- Examine Relationships: Identifying correlations and interactions between variables.

- Test Assumptions: Ensuring the dataset meets the assumptions of the statistical methods (e.g., linearity, homoscedasticity, independence).

P-P plots were observed to test the normality of the data, and skewness and kurtosis statistics were considered. The initial observation and considerations of these tests confirmed that the data were normally distributed.

4.5.3 Correlation Analysis

Correlation analysis quantifies the degree to which two variables move in relation to each other (Hair et al., 2018). The results are expressed as a correlation coefficient ranging from -1 to +1. A coefficient of +1 indicates a perfect positive relationship. A coefficient of -1 indicates a perfect negative relationship. A coefficient near 0 suggests no linear relationship. Statistical significance was determined as $p < 0.05$ testing at the 0.95 (*) and 0.99 (**) confidence levels. A Pearson's Correlation test measures the strength of the linear relationship between two continuous variables. The assumptions tested for the analysis were that the variables were measured at the interval level and that the data must approximate normality.

Having established that the data were normally distributed and that the variables were measured at the interval level, it is necessary to conduct the correlation analysis to identify which variables were statistically significantly related and the direction of the relationships. This: 1) helps to understand the interaction between the variables better, and prepares the researcher to anticipate likely analysis outcomes in the following analyses; and 2) adds to the rigour of the statistical analysis. Only statistically significant results were reported.

The correlation analysis can: a) use the Pearson correlation analysis as a test for the MANOVA assumption of linearity; and b) triangulate the MANOVA tests for statistical significance. It also fulfils the primary purpose of the study, which was to detect whether there was a statistically significant difference between the different chess-rated players' NAPLAN test scores per ratings categories (group) and: i) their own NAPLAN scale scores; and ii) the Queensland state average NAPLAN scores.

4.5.4 Multivariate Analysis of Variance (MANOVA)

MANOVA analyses the relationship between multiple dependent variables and one or more independent variables (Hair et al., 2018). It is particularly valuable in research where the dependent variables are interrelated, such as the NAPLAN numeracy and literacy standardised test scores, allowing researchers to examine their combined effects simultaneously rather than evaluating each variable separately. Univariate analysis of independent variable effects on a single dependent variable would require separate Analysis of Variance (ANOVA) tests. This would increase the possibility of achieving Type-1 errors (false positive) and of failing to capture the dependent variables' interactions.

The purpose of using MANOVAs includes explicitly:

- Testing Multivariate Differences: MANOVA determines whether group means on a combination of dependent variables differ significantly based on the levels of the independent variable(s).
- Understanding Interactions: MANOVAs identify how independent variables interact and jointly impact multiple outcomes, offering more profound insights into complex relationships.
- Reducing Type I Errors: By assessing multiple dependent variables in a single analysis, MANOVA minimises the risk of Type I errors (false positives) compared to conducting multiple univariate tests (like separate ANOVAs) (Hair et al., 2018).

In order to conduct a MANOVA, certain assumptions must be met. These include:

1. Multivariate Normality

The dependent variables should follow a multivariate normal distribution within each independent variable group(s).

This assumption means that the combination of dependent variables, rather than each individually, should exhibit normality, as measured by Tukey's Honest Significant Difference (HSD) test.

2. Homogeneity of Covariance Matrices

The variance-covariance matrices of the dependent variables should be equal across all groups. This is often tested using Box's M Test. Significant results from this test suggest a violation of this assumption.

3. Independence of Observations

Observations should be independent of one another, meaning that the data points for one subject or case should not influence the data points for another. This assumption is crucial and is typically ensured through proper study design. The Levene's test was adopted for this purpose.

MANOVA tests assume equal variances across groups for valid results. Levene's test is used to assess the homogeneity of variance across groups, which is a key assumption in statistical tests like ANOVA and MANOVA.

Levene's Test determines whether the variance of the dependent variable is equal across different groups defined by an independent variable. If Levene's test is significant ($p < .05$), it suggests that variances are not equal, meaning the assumption of homogeneity of variance is violated. If Levene's test is not significant ($p > .05$), then the assumption holds, and equal variances can be assumed.

4. Linearity

The relationships between pairs of dependent variables should be linear. This assumption is necessary because MANOVA evaluates the combined impact of dependent variables. To test this assumption, P-P plots were observed for linearity and correlation analysis tests for statistical significance was used.

5. Adequate Sample Size

MANOVA requires a sufficient sample size, particularly in relation to the number of dependent variables. A general rule is that the sample size for each group should exceed the number of dependent variables. Small sample sizes can lead to instability in results.

6. No Multicollinearity

The dependent variables should not be highly correlated with one another. If multicollinearity exists, it might compromise the accuracy of the analysis, as MANOVA relies on distinct contributions of each dependent variable.

7. Outliers

The presence of multivariate outliers can distort the results of MANOVA. Identifying and addressing any outliers before the analysis is essential, typically using tools like Mahalanobis distance.

These assumptions were tested before conducting the MANOVA with the relevant results presented in Chapter Five. No extreme univariate outliers were identified by examining the P-P plots, skewness and kurtosis statistics. Mahalanobis distance was used to assess the assumption of no extreme multivariate outliers. The assumption of linearity was considered for the dependent variable in each independent group as per inspection of the scatterplots. Pearson's Correlation was used to examine the relationship between the dependent variables and the assumption of no multicollinearity or singularity. The assumption of homogeneity of variance and covariance was tested using Box's M and Levene's test.

As per standard MANOVA analysis procedures, statistically significant group differences require an ANOVA to test further for significance, effect size and observable power (Hair et al., 2018).

4.5.5 One sample T-Test

A one-sample t-test is a statistical method used to determine whether the mean of a single sample significantly differs from a known value or population mean. It is widely used in research to test hypotheses about population characteristics based on sample data (Adhikari et al., 2023). The test assesses whether the observed sample mean (students' chess ratings groups and mean student NAPLAN scores) significantly differs from a hypothesised value, being the NAPLAN population means per test for Grammar and Punctuation; Numeracy; Reading; Spelling; and Writing. T-Tests are beneficial when evaluating whether a group differs from a standard (Adhikari et al., 2023; Cohen et al., 2008). The T-

Tests also compared the mean of chess-rated gender, LBOTE, school type and school group student means against the Queensland state NAPLAN test scores.

Typically, hypothesis testing includes testing for the null hypothesis (H_0: There is no significant difference between the sample mean and the population mean). If the null hypothesis is rejected (the t-statistic exceeds the critical value ($p< 0.05$), the alternative hypothesis (H_1: The sample mean is significantly different from the population mean) is regarded as true and that there is a statistically significant difference between the sample mean and the population mean.

The assumptions that need to be met for conducting valid one-sample T-tests include:

- The sample data are drawn from a population with a normal distribution.
- The data are measured at an interval scale.
- Observations within the sample are independent.

These assumptions were tested in the previous statistical analyses and, as such, the study confirmed that the assumptions for T-Testing were met.

4.6 Validity and Reliability Considerations

Existing, scaled data from two highly reliable sources (the QCAA and the QJRL) were used for this study. The data from the QCAA were based on the NAPLAN standardised testing, which undergoes annual validity and reliability testing. The QJRL ratings were based on the FIDE-adopted Elo scale described above, and were confirmed as valid and reliable (Berg, 2020). As such, it was concluded that the measurement scales and ratings were valid and reliable. Therefore, the secondary data for this study were valid and reliable measurements of the variables of interest. The sample size is critical to the validity and reliability of the findings. The widely accepted benchmark for adequate sample size is 5 cases per variable. The study included 13 variables (four independent, five dependent and three interacting variables), suggesting that the minimum number of valid cases should be at least n=65. The study included 255 students representing 810 cases of participating in NAPLAN tests. This exceeded the sample size adequacy measure and suggested that the results were valid. The cases also represented approximately 10% of the total number of rated chess students, yielding a high statistical power.

4.7 Limitations of the Method

Limitations of MANOVA (Multivariate). The research design had several limitations, including those associated with the analysis techniques and the study's non-random sampling.

MANOVA

- Assumptions Must Be Met: MANOVA relies on assumptions such as multivariate normality, homogeneity of covariance matrices and linear relationships among dependent variables. Violations can lead to inaccurate results. The study strongly emphasised using appropriate testing to meet this assumption.
- Complex Interpretation: Unlike ANOVA, MANOVA considers multiple dependent variables simultaneously, making interpretation more difficult. Researchers must carefully analyse which variables drive significant findings. The study used $p < 0.05$ to test for significance, and, owing to the limited number of dependent variables and the close relationship between spelling, reading, writing, and grammar and punctuation associated with literacy, complexity was low.
- Sensitivity to Sample Size: MANOVA requires a sufficiently large sample to produce reliable results. Small samples can lead to unstable estimates and reduced power. As noted above, the study determined that the 255 valid cases and the 807 data points representing the independent variables and the large number of data points aggregated in the dependent variables illustrated adequate sampling and strong statistical power.
- Multicollinearity Issues: The test may lose effectiveness and distort results if dependent variables are highly correlated. The study conducted correlation analysis, which examined the pairwise correlation coefficients between independent variables. Correlations above 0.8 or 0.9 often indicate

multicollinearity but were missing from the results, suggesting no multicollinearity issues.

- Inability to Determine Causal Relationships: MANOVA identifies group differences but does not establish causation. This was recognised in the research design, and, therefore, the analysis concluded with conducting one-sample T-tests.*T-Test (One-Sample)*
- Assumption of Normality: T-tests assume that the data follow a normal distribution. If this assumption is violated, results may be misleading. As noted above, a normal distribution of data was established.
- Limited to Comparing Means: T-tests evaluate only mean differences between groups and do not account for variance or distribution differences. The research design recognised and addressed this by including tests for the normal distribution discussed above and Levene’s test for variance. The results indicated a normal distribution and acceptable levels of variance.
- Assumption of Homogeneity of Variance: The independent samples t-test assumes equal variance between groups. The results of the MANOVA analysis indicated equal variance between the groups in the analysis.
- Limitations of Non-Random (Purposive) Sampling**:** Since participants are selected intentionally rather than randomly, there is potential bias, and results may be skewed based on researcher selection criteria. This was not the case in the study because the sampling was convenient, with no other criteria than contact ability and willingness to consent being applied. In other words, the researcher’s selection criteria did not include respondent characteristics. This was still a limitation of the study, and future research is encouraged to address this limitation by including a randomised sampling strategy.
- Limited Generalisability: Findings cannot be confidently applied to the larger population, reducing external validity. While the sample had strong statistical power, randomised sampling would increase external validity, and future studies should consider this in their research design.
- Risk of Overrepresentation: Specific groups may be overrepresented, leading to conclusions that do not accurately reflect broader trends. In

observing the descriptive statistics, the groups were generally equally represented, and no overrepresentation was apparent.

- Randomisation was not possible in this study which was based on existing data.
- Advanced econometric techniques were not used in this study.
- To some extent selection was skewed towards students who had left school at the time of gaining consents. This was because it was not normally possible to contact students who were still at school, whereas, while it was not easy, students who had left school could be contacted.

Each method has strengths and ideal use cases, but recognising their limitations ensures more informed and reliable research outcomes. A strength of the study was that the four independent variables included 189 schools, compared to just one school included in the Poston and Vandenkieboom (2019) study. The number of schools involved in the study represented 10.5% of the total number of schools (1797 as of 2023) in Queensland. This addressed the limitations of generalisation and representation noted above, allows causal calculations and involves existing data and class means. It also provides an opportunity to broaden the study in collaboration with Education Queensland to study the entire QJRL database, rather than being limited by having the researchers gain individual consent.

4.8 Ethical Considerations

The final part of this chapter focuses on the ethical considerations addressed by the researcher before and during the study. It is widely recognised that researchers should anticipate potential ethical challenges (Creswell, 2009). Ethical standards are crucial to maintaining the integrity of the research process, the researcher and the participants involved (Neuman, 2006). To uphold these standards, various institutional and academic measures were implemented.

At the start of the project, ethical guidelines established by university policies and overseen by the Human Research Ethics Committee (HREC) of the University of Southern Queensland were integrated into the research design. USQ Ethics Committee H20REA216 approved Human Ethics Clearance on 17

September 2020, valid until 17 September 2023 (see Appendix 1). CAQ approved the use of QJRL data for this study (see Appendix 2). Researchers must follow these guidelines, safeguard participants' rights and interests, and submit a report after the project's conclusion. Ethical considerations such as voluntary participation, anonymity, confidentiality, avoiding deception and accurate reporting (Zikmund, 2003) were thoroughly addressed before and throughout the research process.

The participant invitation to consent clearly explained the research purpose, anonymity protocols, the right to withdraw at any time, confidentiality measures and the opportunity to raise concerns. The researcher's contact information was provided in all communications. No ethical issues were reported during the study.

Data collection, management and reporting strictly adhered to ethical guidelines to safeguard respondents' privacy and confidentiality (Neuman, 2006). Participants were informed that their responses would be automatically anonymised, ensuring their identity remained unknown to external parties. Participants were also assured that the results would be used solely for academic purposes (Neuman, 2006). This ensured both ethical compliance and the integrity of the data.

In addition to these measures, the QCAA ethics safeguards provided reassurance that the study met all ethical obligations.

4.9 Conclusion

In response to the conceptual model underpinning the study and the research questions and hypotheses, this chapter outlined the methodological approach and the research design guiding the study to respond to the research questions adequately. The study was an explanatory longitudinal study. The paradigmatic lens viewing the research methodology was postpositivist. The secondary data were derived from NAPLAN standardised numeracy and literacy test scores and QJRL rating scales. The sampling was purposive and non-random, dependent on respondents' consent to match their NAPLAN scores to their QJRL ratings. A statistical analysis strategy was applied to meet the assumptions required for analysis techniques rigorously and to respond to the study hypotheses. These were: 1) Descriptive statistics to understand the demographics of the respondents and to determine the level of normal distribution of the data; 2) Correlation analysis to evaluate levels of multicollinearity and to understand the nature of the relationship between the variables; 3) MANOVA to determine if statistically significant differences were present among the independent variable groups; and 4) T-Tests to determine if there were statistically significant differences between the independent variable groups and each of the state averages for the five NAPLAN test scores.

The limitations of the research design were discussed and addressed. The ethical considerations and approvals for the study were presented. Chapter Five presents the results of the analyses.

CHAPTER 5: RESULTS

5.1 Introduction

This chapter presents the statistical results of the study. The results are presented in the sequence set out in Section 4.5 (Analysis Techniques). The results are presented as per the American Psychological Association (APA) guidelines.

The study sought to investigate whether students practising and competing in chess over time (up to seven years) as operationalised by Queensland chess rating groups had measurable standardised test score differences: a) from their own NAPLAN scores over time; and b) from the Queensland state NAPLAN score averages. The study was longitudinal in nature with: i) independent variables operationalising extra chess practice and competition as “Chess Ratings Groups” across four groups described as “Novice”, “Rookie”, “Intermediate” and “Advanced” players; gender; school type; school group; home language other than English; and year level; and ii) dependent variables measuring: a) students’ own standardised literacy (Grammar & Punctuation; Reading; Spelling; Writing) and numeracy test scores as per NAPLAN tests scores; and b) Queensland state NAPLAN numeracy and literacy score averages.

As was also noted in Chapter Four, the analysis techniques were designed to respond rigorously to the research questions by testing the study’s null hypotheses. The research questions and the null hypotheses were:

RQ1: Is there a statistically significant difference between Queensland chess ratings groups and students’ own NAPLAN Scale Scores?

$H1_0$: Chess ratings groups do not significantly differ from students’ own NAPLAN test results in:

f) Scale Score - GP
g) Scale Score - NMCY
h) Scale Score - READ
i) Scale Score - SPEL

j) Scale Score - WRIT

RQ2: Is there a statistically significant difference between Queensland chess rated players in school groups as defined by the density of rated chess players per school and the students' own NAPLAN scale scores?

$H2_0$: Chess rated players in school groups do not significantly differ from students' own NAPLAN test results in:

f) Scale Score - GP
g) Scale Score - NMCY
h) Scale Score - READ
i) Scale Score - SPEL
j) Scale Score - WRIT

RQ3: Is there a statistically significant difference between Queensland chess rated players in school types and the students' own NAPLAN scale scores?

$H3_0$: Chess rated players in school types do not significantly differ from students' own NAPLAN test results in:

f) Scale Score - GP
g) Scale Score - NMCY
h) Scale Score - READ
i) Scale Score - SPEL
j) Scale Score - WRIT

RQ4: Is there a statistically significant difference between Queensland chess rated players in home language other than English groups and the students' own NAPLAN scale scores?

$H4_0$: Chess rated players in LBOTE groups do not significantly differ from students' own NAPLAN test results in:

f) Scale Score - GP
g) Scale Score - NMCY

h) Scale Score - READ
i) Scale Score - SPEL
j) Scale Score - WRIT

RQ5: Is there a statistically significant difference between Queensland chess rated players in gender groups and the students' own NAPLAN scale scores?

$H5_0$ Chess rated players in gender groups do not significantly differ from students' own NAPLAN test results in:

k) Scale Score - GP
l) Scale Score - NMCY
m) Scale Score - READ
n) Scale Score - SPEL
o) Scale Score - WRIT

RQ6: Is there a statistically significant difference between Queensland chess rated players in school year level groups and the students' own NAPLAN scale scores?

$H6_0$ Chess rated players in school year level groups do not significantly differ from students' own NAPLAN test results in:

p) Scale Score - GP
q) Scale Score - NMCY
r) Scale Score - READ
s) Scale Score - SPEL
t) Scale Score - WRIT

RQ7: Is there a statistically significant difference between Queensland chess rating groups and the state average NAPLAN scores?

$H7_0$: Chess rating groups do not statistically differ from the Queensland state average NAPLAN test scores in:

f) Diff NAPLAN Score - GP
g) Diff NAPLAN Score - NMCY

h) Diff NAPLAN Score - READ
i) Diff NAPLAN Score - SPEL
j) Diff NAPLAN Score – WRIT

5.2 Descriptive Statistics

Most Queensland junior chess players commence their rated chess career in the lower grades of their region of the Queensland inter-schools chess tournament, held each term. Once they have reached a minimum standard (chess rating 500 – approximately the ability to move the pieces correctly and do fundamental checkmates) measured by their results against players with a Queensland Junior chess rating, they receive their first rating. Accordingly, most players achieve a first rating of between 500 and 600. A few outliers may do better or arrive from another state or country with much higher playing ability.

Students automatically drop off the list if they are inactive for 18 months. In total, 807 cases (data points) were collected representing the number of NAPLAN tests in which chess rated players were included in the dataset (see Table 3).

Table 3: Case processing summary

Variable	Series Length	User-Missing
Ratingmax Group	807	0
Year Level	807	0
School Group	807	0
School Type	807	0
LBOTE Group	807	0
Gender Group	807	0
Diff_NAPLAN_GP	807	0
Diff_NAPLAN_NMCY	807	0
Diff_NAPLAN_READ	807	0
Diff_NAPLAN_SPEL	807	0
Diff_NAPLAN_WRIT	807	0
Scale Score GP	807	0
Scale Score NMCY	807	0
Scale Score READ	807	0

Variable	Series Length	User-Missing
Scale Score SPEL	807	0
Scale Score WRIT	807	0

Descriptive statistics include mean, standard deviation (SD), skewness and kurtosis statistics. Table 4 indicates the descriptive statistics of all the variables included in the study.

Table 4: Descriptive statistics: Students with chess ratings

Variable	N	Mean	Std. Deviation	Skewness	Std. Error	Kurtosis	Std. Error
Ratingmax Group	807	2.19	1.202	0.457	0.086	-1.356	0.172
Year Level	807	6.24	2.172	-0.137	0.086	-1.270	0.172
School Type	807	2.97	1.743	0.434	0.086	-0.940	0.172
School Group	807	2.01	0.818	-0.021	0.086	-1.504	0.172
Gender Group	807	1.23	0.418	1.316	0.086	-0.269	0.172
LBOTE Group	807	1.66	0.475	-0.667	0.086	-1.559	0.172
Scale Score GP	796	603.90	96.16	-0.105	0.087	0.321	0.173
Scale Score NMCY	797	631.60	110.67	-0.123	0.087	-0.332	0.173
Scale Score READ	800	590.78	84.28	-0.436	0.086	0.446	0.173
Scale Score SPEL	796	578.28	89.90	-0.329	0.087	-0.149	0.173
Scale Score WRIT	795	559.04	86.31	-0.035	0.087	-0.142	0.173
Diff_NAPLAN_GP	784	88.04	78.08	0.366	0.087	0.540	0.174
Diff_NAPLAN_NMCY	785	115.69	80.74	0.320	0.087	0.027	0.174
Diff_NAPLAN_READ	788	74.86	63.90	0.177	0.087	0.333	0.174
Diff_NAPLAN_SPEL	784	62.61	63.32	-0.021	0.087	-0.025	0.174
Diff_NAPLAN_WRIT	783	43.44	64.20	-0.100	0.087	0.223	0.175
Valid N (Listwise)	780	-	-	-	-	-	-

To evaluate the normality of the data, skewness and kurtosis statistics were examined alongside probability-probability (P-P) plots (see Appendix D). Skewness and kurtosis values for all variables fell within acceptable limits (skewness < |2.0|, kurtosis < |7.0|) (West et al., 1995), indicating no substantial departures from normality. Additionally, visual inspection of the P-P plots demonstrated that the observed data closely followed the expected normal distribution, further supporting the assumption of normality.

5.2.1 Frequencies

The number of NAPLAN tests that the chess rated student cohort had completed is presented in Table 5.

Table 5: NAPLAN test totals for chess rated students

	Frequency	Percent	Cumulative Percent
2008	54	6.7	6.7
2009	64	7.9	14.6
2010	75	9.3	23.8
2011	99	12.2	36.0
2012	72	8.9	44.9
2013	98	12.1	57.0
2014	57	7.0	64.1
2015	86	10.6	74.7
2016	46	5.7	80.4
2017	56	6.9	87.3
2018	31	3.8	91.1
2019	24	3.0	94.1
2021	15	1.9	95.9
2022	21	2.6	98.5
2023	12	1.5	100.0
Total	810	100.0	

There were no NAPLAN tests in 2020 owing to the COVID-19 epidemic. Table 6 illustrates how many chess rated students participated in NAPLAN tests per year level. These were generally evenly distributed.

Table 6: Chess rated participation in NAPLAN tests per year level

Year Level	Frequency	Percent	Cumulative Percent
3	161	19.9	19.9
5	205	25.3	45.2
7	222	27.4	72.6
9	222	27.4	100
Total	810	100	

Table 7 indicates the types of schools where chess rated students also participated in NAPLAN tests. The number of state schools made up 46% of the sample, suggesting an almost even distribution of state and private schools. However, the number of state schools in the study as a proportion of the total number of state schools in Queensland (1262) was a participation rate of 7%.

The number of private schools with chess rated players was 102 out of a total of 529 Queensland private schools, suggesting a participation rate of 19%.

Table 7: School types of chess rated players

School Type Summary		
State	1	87
Catholic	2	50
Christian	3	15
Anglican	4	11
Independent	5	12
Lutheran	6	11
Other	7	3
Total		**189**

Table 8 indicates a female participation rate of 21% in this study, which was higher than the 11-15% participation in chess tournaments generally shown in chess literature.

Table 8: Gender of chess rated players

Participation	Total	Male	Female	Frequency
All four NAPLAN years	127	94	33	508
Three NAPLAN years	66	55	11	198
Two NAPLAN years	42	35	7	84
One NAPLAN year	20	17	3	20
Total	**255**	**201**	**54**	**810**
		78.82%	**21.18%**	

Table 9 indicates that approximately one-third of students in the study spoke a language other than English at home. These were almost entirely of Chinese or Indian background.

Table 9: LBOTE chess rated students (home language other than English)

	Frequency	Percent	Cumulative Percent
Not stated	3	0.4	0.4
Non LBOTE	531	65.6	65.9
LBOTE	276	34.1	100
Total	810	100	

In Table 10, schools were grouped according to the participation in rated events and the participation density of participation to school population. This served as an indication of schools enabling a culture of chess:

Group 1 - 6 schools (Total 265 frequencies) - high chess density

Group 2 – 33 Schools (Total 270 frequencies) - medium chess density

Group 3 – 150 Schools (Total 275 frequencies) - low chess density

Table 10: School groups according to chess rated player density

Participation	Number of Schools	Frequency	Percent
Group 1	6	265	32.7
Group 2	33	270	33.3

Group 3	150	275	34
Total	**189**	**810**	**100**

Note: Mahalanobis distance was used to assess the assumption of no extreme multivariate outliers. As a result, the frequencies (810) were reduced to 807 during the statistical analysis process.

5.3 Correlations Analysis

The correlation analysis sought to identify statistically significant relationships (+ and -) between the variables of interest at the 0.99(**) and 0.95(*) confidence levels. These were indicated when p<0.05 and p<0.01 using Pearson correlation tests. Only correlations at these levels of significance were reported here.

5.3.1 Pearsons Correlations

Table 11: Pearson correlations between variables of the study (p < 0.05)

Variable	Rating max Group	Year Level	School Group	School Type	Gender Group	LBOTE Group	Diff_NAPLAN_GP	Diff_NAPLAN_NMCY	Diff_NAPLAN_READ	Diff_NAPLAN_SPEL	Diff_NAPLAN_WRIT	Scale Score GP	Scale Score NMCY	Scale Score READ	Scale Score SPEL	Scale Score WRIT
Ratingmax Group	1.000	.057	-.088*	.083*	-.179**	-.134**	.053	.160**	.050	.112**	.086*	.079*	.151**	.073*	.114**	.106**
Year Level	.057	1.000	-.121**	.187**	-.012	.006	-.049	.231**	-.071*	.083*	.006	.552**	.681**	.623**	.693**	.667**
School Group	-.088*	-.121**	1.000	-.462**	-.102**	.198**	-.055	-.105**	-.072*	-.135**	-.151**	-.129**	-.148**	-.150**	-.186**	-.211**
School Type	.083*	.187**	-.462**	1.000	.122**	.018	.033	.011	.033	.063	.140**	.147**	.114**	.158**	.173**	.239**
Gender Group	-.179**	-.012	-.102**	.122**	1.000	-.011	.200**	-.112**	.104**	.126**	.228**	.154**	-.087*	.067	.082*	.161**
LBOTE Group	-.134**	.006	.198**	.018	-.011	1.000	-.130**	-.171**	-.011	-.201**	-.028	-.117**	-.137**	-.021	-.154**	-.030
Diff_NAPLAN_GP	.053	-.049	-.055	.033	.200**	-.130**	1.000	.490**	.597**	.609**	.450**	.791**	.339**	.429**	.406**	.312**
Diff_NAPLAN_NMCY	.160**	.231**	-.105**	.011	-.112**	-.171**	.490**	1.000	.497**	.504**	.362**	.545**	.857**	.546**	.511**	.433**

Diff_NAPLAN_ READ	.050	-.071*	-.072*	.033	.104**	-.011	.597**	.497**	1.000	.500**	.446**	.447**	.330**	.717**	.311**	.289**
Diff_NAPLAN_ SPEL	.112**	.083*	-.135**	.063	.126**	-.201**	.609**	.504**	.500**	1.000	.466**	.547**	.413**	.439**	.760**	.405**
Diff_NAPLAN_ WRIT	.086*	.006	-.151**	.140**	.228**	-.028	.450**	.362**	.446**	.466**	1.000	.354**	.253**	.325**	.315**	.731**
Scale Score GP	.079*	.552**	-.129**	.147**	.154**	-.117**	.791**	.545**	.447**	.547**	.354**	1.000	.709**	.748**	.766**	.662**
Scale Score NMCY	.151**	.681**	-.148**	.114**	-.087*	-.137**	.339**	.857**	.330**	.413**	.253**	.709**	1.000	.742**	.753**	.672**
Scale Score READ	.073*	.623**	-.150**	.158**	.067	-.021	.429**	.546**	.717**	.439**	.325**	.748**	.742**	1.000	.735**	.685**
Scale Score SPEL	.114**	.693**	-.186**	.173**	.082*	-.154**	.406**	.511**	.311**	.760**	.315**	.766**	.753**	.735**	1.000	.722**
Scale Score WRIT	.106**	.667**	-.211**	.239**	.161**	-.030	.312**	.433**	.289**	.405**	.731**	.662**	.672**	.685**	.722**	1.000

Note. *. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

5.3.2 Correlations – Interpretation

The Pearson correlation analysis examined relationships among Ratingmax Group, Year Level, School Group, School Type, Gender Group, LBOTE Group, NAPLAN Differences (GP, NMCY, READ, SPEL, WRIT) and Scale Scores. Below is a detailed breakdown of strong, moderate and weak correlations, as well as notable inverse relationships.

1. Strong Correlations ($r > .70$, $p < .01$)

These correlations indicated highly significant relationships between variables, meaning that performance in one category strongly predicted change in another.

a. Year Level and Scale Scores

- Year Level of chess players strongly correlated with Scale Score NMCY ($r = .681$, $p < .01$), Scale Score READ ($r = .623$, $p < .01$), Scale Score SPEL ($r = .693$, $p < .01$) and Scale Score WRIT ($r = .667$, $p < .01$).
- Students in higher year levels and therefore practising and competing in chess for longer consistently demonstrated higher individual scores against the state average NAPLAN score for numeracy, spelling and writing.

b. NAPLAN Differences and Scale Scores

- Diff_NAPLAN_NMCY correlated highly with Scale Score NMCY ($r = .857$, $p < .01$).
- Diff_NAPLAN_READ correlated highly with Scale Score READ ($r = .717$, $p < .01$).
- Diff_NAPLAN_SPEL correlated highly with Scale Score SPEL ($r = .760$, $p < .01$).
- Diff_NAPLAN_WRIT correlated highly with Scale Score WRIT ($r = .731$, $p < .01$).

These findings suggested that students with higher individual NAPLAN scale scores also showed strong correlations and increased against the state average NAPLAN scores.

2. Moderate Correlations (r = .30–.69, p < .01)

These correlations indicated moderate but meaningful relationships between variables.

a. School Type and Academic Outcomes

- School Type correlated moderately with Scale Score GP (r = .147, p < .01), Scale Score READ (r = .158, p < .01) and Scale Score WRIT (r = .239, p < .01).
- This suggested that students practising and competing in chess in certain school types moderately improved their GP, READ and WRIT NAPLAN scores.

b. Gender Differences in Numeracy and Writing

- Gender Group negatively correlated with Scale Score NMCY (r = -.087, p < .05).
- Gender Group positively correlated with Scale Score WRIT (r = .161, p < .01).
- Males tended to perform better in numeracy, whereas females performed better in writing.

3. Weak Correlations (r < .30, p < .05 or p > .05)

These correlations indicated weak or negligible relationships between variables, meaning that changes in one did not reliably affect another.

a. LBOTE Status and NAPLAN Performance

- LBOTE Group showed weak correlations across all variables, with the highest correlation at r = -.201 with Diff_NAPLAN_SPEL (p < .01).
- Students from diverse language backgrounds performed similarly to their peers across NAPLAN domains.

b. Ratingmax Group and School Group

- Ratingmax Group showed weak positive correlations with Diff_NAPLAN_NMCY (*r* = .160, *p* < .01) and Scale Score NMCY (*r* = .151, *p* < .01).
- School Groups had weak correlations positively related to numeracy that likely reflected the density of chess players in certain schools.

4. Inverse Relationships (Negative Correlations, r < 0, p < .05 or p < .01)
These correlations indicated negative associations, meaning that an increase in one variable correlated with a decrease in another.

a. Gender and Numeracy Scores

- Gender Group negatively correlated with Scale Score NMCY (*r* = -.087, *p* < .05), meaning males tended to score higher in numeracy.

Final Summary of Correlation Analysis

A statistically significant finding in this study from the correlations was that students who reached their teenage years and earned a high chess rating improved their own NAPLAN scores between Grades Three and Nine and an improvement against the state average over the same period.

There were also convincing findings for the generally held belief that boys scored higher in numeracy and girls scored higher in literacy. While the girls scored higher in spelling, reading and writing, there was no indication that this was the case for grammar and punctuation.

There were also less convincing positive findings for LBOTE students, for those who attended Anglican and catholic schools, and for those who attended schools with a higher chess density.

5.4 MANOVA Analysis

5.4.1 Introduction

MANOVAS were conducted. They were chosen to include independent variables that may have had a statistically significant impact on NAPLAN scores: chess rating groups that were indicative of playing activity (practising and competing) and playing strength (ratings), gender, year level, school type and school groups. The latter was indicative of the density of rated chess players in schools.

To conduct the MANOVAS, the independent variables were placed into groups, according to Table 12.

Table 12: Independent variables of the study

Independent variable	Group 1	Group 2	Group 3	Group 4
Rating Max	500 - 799	800 - 999	1000 - 1199	>=1200
Year Level	3	5	7	9
LBOTE	Students with a home language other than English	Students with English as a home language		
School Group	Schools with the highest number of frequencies in the data	Schools in the middle	Schools with the lowest number of frequencies in the data	
Gender	Male	Female		

To conduct the MANOVAS, the dependent variables included: i) chess rated students' own NAPLAN scores (SCALE_SCORE_Y); and ii) state average NAPLAN scores (diff_NAPLAN_Y).

5.4.2 Assumption Testing

The following assumption tests are required prior to proceeding with a MANOVA analysis:

Multivariate normality

The dependent variables should follow a multivariate normal distribution within each independent variable group(s). There were no extreme univariate outliers as assessed by the examination of the PP-plots (see Appendix C). The results of the Tukey's HSD results indicated that this assumption was met.

Homogeneity of covariance

Homogeneity of covariance matrices were evaluated using Box's M test. Box's M was not statistically significant, p = .194, indicating that the assumption of equal covariance matrices across groups was met. The test results are summarised in Table 13.

Table 13: Box's M Test for Homogeneity of Covariance Matrices

Test Statistic	Value
Box's M	320.329
F	1.089
df1	195
df2	4848.163
Sig.	.194

Note. Box's M tested the null hypothesis that the observed covariance matrices of the dependent variables were equal across groups.

Multivariate Normality

Multivariate normality was assessed using a series of multivariate tests, including Roy's Largest Root. These tests examined whether the dependent variables followed a multivariate normal distribution across different categorical groups. The significance values (**p**) and effect sizes (Partial Eta Squared) provided insight into the strength of the multivariate relationships, as presented in Table 14.

Table 14: Multivariate Analysis of Variance (MANOVA) results for multivariate normality

Multivariate Tests								
	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Roy's largest root Scale_Score	.035	2.857b	5.000	403.000	.015	.034	14.286	.841
Roy's largest root diff_NAPLAN	.031	2.492[a]	5.000	404.000	.031	.030	12.462	.780
Each F tests the multivariate effect of the dependent variables. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.								
a. The statistic is an upper bound on F that yields a lower bound on the significance level.								
b. Computed using alpha = .05.								

For the SCALE_SCORE_Y dependent variables, the significance level of *p* = 0.015 suggested statistical significance, meaning the effect was likely not due to chance. The correlation of 0.841 indicated a strong association. This test suggested that the effect was statistically significant and contributed meaningfully to the model.

For the diff_NAPLAN_Y dependent variables, the significance level of *p* = 0.031 suggested statistical significance, meaning the effect was likely not due to chance. The correlation of 0.780 indicated a strong association. This test suggested that the effect was statistically significant and contributed meaningfully to the model.

Homogeneity of Variance

Levene's test was conducted to examine the assumption of equal variances across groups for each dependent variable. This test assessed whether the variance of the dependent variables was consistent across different levels of the independent variable.

The results (see Table 15) indicated that, for several variables (diff_naplan_gp, diff_naplan_nmcy, diff_naplan_read, diff_naplan_spel and Wdiff_naplan_writ), Levene's test was not statistically significant based on the median. With adjusted degrees of freedom, significance levels varied, indicating that variance differences were not extreme.

Table 15: Levene's Test of Equality of Error Variances for diff_NAPLAN_Y dependent variable

Variable	Method	Levene Statistic	df1	df2	Sig.
diff_naplan_gp	Based on median (adj. df)	1.117	172	137.125	.249
diff_naplan_nmcy	Based on median (adj. df)	.862	172	217.531	.845
diff_naplan_read	Based on median (adj. df)	1.375	172	208.746	.014
diff_naplan_spel	Based on median (adj. df)	1.138	172	174.134	.198
diff_naplan_writ	Based on median (adj. df)	.792	172	168.647	.936

The results of Levene's test of equality of error provided evidence that the assumption of homogeneity of variance and independence of the variables across groups was tenable for all diff_NAPLAN variables except the NAPLAN reading variable, with p values all greater than .05 (see Table 16).

Table 16: Levene's Test of Equality of Error Variances for diff_NAPLAN_Y dependent variable

Variable	Method	Levene Statistic	df1	df2	Sig.
SCALE_SCORE_GP	Based on Median (adj. df)	2.194	3	757.416	.087
SCALE_SCORE_NMCY	Based on Median (adj. df)	.478	3	789.051	.698
SCALE_SCORE_READ	Based on Median (adj. df)	7.547	3	731.410	<.001
SCALE_SCORE_SPEL	Based on Median (adj. df)	3.386	3	781.829	.018
SCALE_SCORE_WRIT	Based on Median (adj. df)	3.597	3	772.068	.013

The results of Levene's test of equality of error provided evidence that the assumption of homogeneity of variance and independence of the variables across groups was tenable for all SCALE_SCORE_Y variables. The GP, READ, WRIT and SPEL variables had p values all smaller than .05 (see Table 19). This result was expected owing to the variables cumulatively measuring "literacy" according to the NAPLAN scale. As such, the MANOVA assumption of homogeneity of covariance was met for the NMCY variable, suggesting no covariance with the cumulative "literacy" variables assuming equal variance between GP, READ, WRIT and SPEL variables.

Linearity

The relationships between pairs of dependent variables should be linear. This assumption was tested by observing P-P plots (see Appendix D) for linearity and correlation analysis (see Table 14) tests for statistical significance. The tests showed that linearity was observed across all data.

Adequate Sample Size

The sample size significantly exceeded guidelines for sampling adequacy.

Outliers

The presence of multivariate outliers can distort the results of MANOVA. Identifying and addressing any outliers before the analysis is essential, typically using tools like Mahalanobis distance. Mahalanobis distance was used to assess the assumption of no extreme multivariate outliers. The critical value was 20.515, with three data points exceeding this value that were removed during the screening of data phase prior to analysis.

5.4.3 MANOVA and Post Hoc ANOVA Analysis Results

With all assumptions tested and met, a pairwise multivariate analysis of variance (MANOVA) was conducted to investigate if there were a significant difference between chess ratings groups, gender, school type, year level and school group students' NAPLAN scale scores in a linear combination of Grammar and Punctuation (SS_GP) and Numeracy (SS_NMCY) and Reading (SS_READ) and Spelling (SS_SPEL) and Writing (SS_WRIT).

The following indications of significance, effect and power were used:

Significance: p = <0.05

Effect: partial η2

0.01 → Small effect

0.06 → Medium effect

0.14 or higher → Large effect

Observed power:

>0.80 → High observed power <0.50 → Low observed power

5.4.3.1 Multivariate Analysis of Variance (MANOVA) Results: Between-Subjects Effects and post hoc ANOVA results for significant findings

A MANOVA was conducted to examine whether multiple independent variables significantly impacted: a) chess playing individuals' performance over time on their own scale scores (SCALE_SCORE); and b) individuals' performance over time compared to the Queensland state average NAPLAN scores (DIFF_NAPLAN). The Type III Sum of Squares, F-values, p-values, effect sizes (Partial Eta Squared) and observed power provided insight into which factors contributed to variation across groups over seven years (across yr3, yr5, yr7, yr9).

a. ***MANOVAs: Effect on chess playing individuals' performance over time on own NAPLAN scores (SCALE_SCORES_Y)***

Key Findings

1. Intercept Effects:

    - The intercept was highly significant ($p < .001$) for all dependent variables, indicating strong baseline effects of predictor variables.
    - The effect sizes (partial $\eta^2 > .95$) suggested an overwhelming variance accounted for by the model.

2. Impact of Rating Group:

    - No significant differences were found across rating groups ($p > .05$) for scale scores or NAPLAN differences, indicating low influence of rating groups on academic performance.
    - Observed power was low (< 0.4), reducing confidence in detecting real effects.

3. Impact of Year Level:

    - Highly significant differences ($p < .001$) were observed across scale scores, with large effect sizes (partial η^2 ranging from .198 to .326).
    - Numeracy (NMCY) was most affected by year level, followed by spelling (SPEL) and reading (READ).
    - NAPLAN differences were significant only for numeracy ($p = .003$, $\eta^2 = .034$).

4. Impact of School Group:

    - Minimal significant effects were observed ($p > .05$), except for spelling (SPEL, p = .052) and NAPLAN spelling difference (p = .056), which approached significance.
    - Observed power was weak (< 0.6), indicating potential limitations in sample size.

5. Impact of School Type:

    - Significant differences across groups ($p < .01$) were found for GP, NMCY, READ and SPEL.

- Writing (WRIT) did not show significant variation (p = .492).
- Effect sizes were moderate (partial η² ~ .043 - .056), suggesting real but small effects.

6. Impact of Gender Group:

- Gender had a significant effect on numeracy (p = .033, η² = .011) and writing (p = .011, η² = .016)**.
- Observed power for gender comparisons ranged from .486 to .723, indicating mixed reliability.

7. Impact of LBOTE (Language Background Other Than English):

- No significant differences (p > .05) were observed across scale scores or NAPLAN differences, indicating LBOTE status did not meaningfully impact performance.

Table 17: Between-Subjects effects for MANOVA for scale scores (performance against individuals' own NAPLAN scores)

Source	***Dependent Variable***	***F***	***p***	***Partial η²***	***Observed Power***
Intercept	*SCALE_SCORE_GP*	*9684.316*	***<.001***	***.959***	***1.000***
	SCALE_SCORE_NMCY	*9273.054*	***<.001***	***.957***	***1.000***
	SCALE_SCORE_READ	*12885.487*	***<.001***	***.969***	***1.000***
	SCALE_SCORE_SPEL	*12964.718*	***<.001***	***.969***	***1.000***
	SCALE_SCORE_WRIT	*12407.334*	***<.001***	***.968***	***1.000***
Ratingmax Group	*SCALE_SCORE_GP*	*1.335*	*.263*	*.010*	*.356*
	SCALE_SCORE_NMCY	*1.113*	*.344*	*.008*	*.300*
	SCALE_SCORE_READ	*0.961*	*.411*	*.007*	*.263*
Year Level	*SCALE_SCORE_GP*	***34.111***	***<.001***	***.198***	***1.000***
	SCALE_SCORE_NMCY	***66.614***	***<.001***	***.326***	***1.000***
	SCALE_SCORE_READ	***48.082***	***<.001***	***.258***	***1.000***
School Group	*SCALE_SCORE_GP*	*0.029*	*.972*	*.000*	*.054*
	SCALE_SCORE_NMCY	*0.212*	*.809*	*.001*	*.083*
School Type	*SCALE_SCORE_GP*	***3.135***	***.005***	***.043***	***.920***
	SCALE_SCORE_NMCY	***2.939***	***.008***	***.041***	***.899***
	SCALE_SCORE_SPEL	***4.069***	***.001***	***.056***	***.975***
Gender Group	*SCALE_SCORE_GP*	*3.722*	*.054*	*.009*	*.486*
	SCALE_SCORE_NMCY	***4.573***	***.033***	***.011***	***.569***
	SCALE_SCORE_WRIT	***6.539***	***.011***	***.016***	***.723***
LBOTE Group	*SCALE_SCORE_GP*	*0.040*	*.841*	*.000*	*.055*
	SCALE_SCORE_NMCY	*1.620*	*.204*	*.004*	*.246*

A summary table of statistically significant results and effect sizes is presented in Table 18.

Table 18: Summary of between-subjects effects for MANOVA

Independent variable	Dependent Variable	F	df	Sig.	Partial η^2	Observed Power
Intercept	All Scale Scores	High	(df)	**< .001**	**High (0.957-0.969)**	**1.000**
Year Level	All Scale Scores	High	(df)	**< .001**	**Moderate-High (0.198-0.326)**	**1.000**
School Type	GP, NMCY, Read, Spel	Moderate	(df)	**< .05**	**Small-Moderate (0.034-0.056)**	**Moderate**
Gender Group	Writing	6.539	(df)	**.011**	**Small (0.016)**	**.723**

Note. Only significant results ($p < .05$) are reported in the summary table.

Interpretation

- Intercepts were highly significant ($p < .001$) across all dependent variables, confirming strong baseline effects.
- Year level had the largest influence on NAPLAN scores, particularly on numeracy ($p < .001$, $\eta^2 = .326$), suggesting that, as the chess players progressed practising and competing in chess over the seven years between NAPLAN scores, there was a significant effect on their scores.
- School type significantly impacted multiple variables, suggesting differences in promoting chess or chess density between school types.
- Gender differences were present in numeracy ($p = .033$) and writing ($p = .011$), but other domains were not significantly affected.
- Ratingmax group, School Group and LBOTE status had minimal or non-significant effects ($p > .05$).

b. *MANOVAs: Group differences related to State Average NAPLAN scores key findings*

Key findings

1. Strong Intercept Effects

- The intercept was highly significant ($p < .001$) for all dependent variables, meaning baseline differences explained a large portion of the variance in NAPLAN scores.
- Effect sizes were substantial ($\eta^2 = .172–.388$), confirming strong initial influences on student performance.

2. Year Level Impact on Numeracy

- Numeracy (NMCY) was significantly affected by year level ($p = .003$, $\eta^2 = .034$, observed power = .905).

3. School Type Influence on Grammar & Punctuation, Numeracy, Reading and Spelling

- Significant effects were observed for GP ($p = .004$, $\eta^2 = .045$), NMCY ($p = .008$, $\eta^2 = .041$), READ ($p = .022$, $\eta^2 = .035$) and SPEL ($p = .001$, $\eta^2 = .056$).

4. Gender Effects on Numeracy and Writing

- Numeracy (NMCY) showed a statistically significant gender difference ($p = .026$, $\eta^2 = .012$).
- Writing (WRIT) was also impacted by gender ($p = .016$, $\eta^2 = .014$).

5. No Significant Impact of Ratingmax Group, School Group or LBOTE Status

- Ratingmax group, school group and LBOTE status did not show statistically significant differences ($p > .05$).

Table 19: Between-Subjects effects of chess playing individuals on state average NAPLAN scores (Diff_NAPLAN)

Source	Dependent Variable	F	p	Partial η²	Observed Power
Intercept	Diff_NAPLAN_GP	**224.02**	**<.001**	**.351**	**1.000**
	Diff_NAPLAN_NMCY	**262.82**	**<.001**	**.388**	**1.000**
	Diff_NAPLAN_READ	**214.75**	**<.001**	**.342**	**1.000**
	Diff_NAPLAN_SPEL	**161.74**	**<.001**	**.281**	**1.000**
	Diff_NAPLAN_WRIT	**85.70**	**<.001**	**.172**	**1.000**
Ratingmax Group	Diff_NAPLAN_GP	1.45	.227	.010	.385
	Diff_NAPLAN_NMCY	1.14	.332	.008	.307
	Diff_NAPLAN_READ	0.98	.402	.007	.267
	Diff_NAPLAN_SPEL	0.56	.643	.004	.165

Source	Dependent Variable	F	p	Partial η²	Observed Power
	Diff_NAPLAN_WRIT	1.32	.268	.009	.352
Year Level	Diff_NAPLAN_GP	0.44	.721	.003	.139
	Diff_NAPLAN_NMCY	**4.84**	**.003**	**.034**	**.905**
	Diff_NAPLAN_READ	0.24	.866	.002	.096
	Diff_NAPLAN_SPEL	0.39	.761	.003	.127
	Diff_NAPLAN_W RIT	1.11	.346	.008	.299
School Group	Diff_NAPLAN_GP	0.04	.956	.000	.057
	Diff_NAPLAN_NMCY	0.19	.826	.001	.080
	Diff_NAPLAN_READ	2.18	.114	.010	.445
	Diff_NAPLAN_SPEL	2.90	.056	.014	.566
	Diff_NAPLAN_WRIT	1.47	.231	.007	.313
School Type	Diff_NAPLAN_GP	**3.23**	**.004**	**.045**	**.928**
	Diff_NAPLAN_NMCY	**2.97**	**.008**	**.041**	**.902**
	Diff_NAPLAN_READ	**2.49**	**.022**	**.035**	**.835**
	Diff_NAPLAN_SPEL	**4.09**	**.001**	**.056**	**.976**
	Diff_NAPLAN_WRIT	0.86	.524	.012	.342
Gender Group	Diff_NAPLAN_GP	3.48	.063	.008	.461
	Diff_NAPLAN_NMCY	**4.98**	**.026**	**.012**	**.605**
	Diff_NAPLAN_READ	0.24	.626	.0006	.078
	Diff_NAPLAN_SPEL	0.62	.431	.0015	.123
	Diff_NAPLAN_WRIT	**5.86**	**.016**	**.014**	**.675**
LBOTE Group	Diff_NAPLAN_GP	0.03	.861	.00007	.054
	Diff_NAPLAN_NMCY	1.69	.194	.004	.255
	Diff_NAPLAN_READ	1.26	.262	.003	.201
	Diff_NAPLAN_SPEL	0.75	.387	.0018	.139
	Diff_NAPLAN_WRIT	0.60	.440	.0014	.121

A summary table of statistically significant results and effect sizes is presented in Table 20.

Table 20: Summary of significant MANOVA effects on state average NAPLAN scores

Source	Dependent Variable	F	p	Partial η²	Observed Power
Year Level	Diff_NAPLAN_NMCY	**4.84**	**.003**	**.034**	**.905**
School Type	Diff_NAPLAN_GP	**3.23**	**.004**	**.045**	**.928**
	Diff_NAPLAN_NMCY	**2.97**	**.008**	**.041**	**.902**
	Diff_NAPLAN_SPEL	**4.09**	**.001**	**.056**	**.976**
Gender Group	Diff_NAPLAN_NMCY	**4.98**	**.026**	**.012**	**.605**
	Diff_NAPLAN_WRIT	**5.86**	**.016**	**.014**	**.675**

Note. Only significant results (p < .05) are reported in the summary table.

Interpretation

1. **Year level significantly impacted numeracy (NMCY, p = .003, η^2 = .034)**, suggesting **stronger numeracy growth compared to the state average over time**.
2. **School type had significant effects on Grammar & Punctuation, numeracy and spelling (p < .01, η^2 > .04)**, emphasising the influence of **school types that promote chess**.
3. **Gender differences were observed in numeracy and writing (p < .05, η^2 = .012–.014)**, indicating **moderate variation between male and female chess players**.
4. **Ratingmax group, school group and LBOTE status showed no significant effects (p > .05)**, meaning there were unobserved differences between these group over time.

5.4.3.2 $H1_0$: Chess ratings groups do not significantly differ from students' own NAPLAN test results in

Scale Score - GP
Scale Score - NMCY
Scale Score - READ
Scale Score - SPEL
Scale Score - WRIT

Results of the MANOVA yielded that there was a statistically significant difference among the four ratings groups on the combined dependent variables, Pillai's Trace=.036, $F(15,2358)$=1.904, p=.019, partial η^2=.012, observed power=.955. Based on these results, evidence was sufficient to reject the null hypothesis and to conclude that, for the maximum rating group, students' scale scores on the five tests differed significantly based on the chess rating group they were in. The effect size was small. The observed power was .955, indicating that there was a 95.5% chance that the results could be shown to be significant.

Based on this result, a one-way ANOVA was conducted for the ratings max groups and the five dependent variables (Scale Score GP, NMCY, READ, SPEL, WRIT) to evaluate significant differences across the groups. The Bonferroni correction was applied at the 0.95 confidence level ($p < .05$) to control for Type I error in multiple comparisons.

Key findings

1. Scale Score Numeracy (NMCY) showed a significant effect, $F(3,791) = 6.164$, $p < .001$, partial $\eta^2 = .023$, observed power = .963. This indicated a statistically meaningful difference across groups.
2. Scale Score Spelling (SPEL) was significant, $F(3,791) = 3.777$, $p = .010$, partial $\eta^2 = .014$, observed power = .815. This suggested moderate differences in spelling performance.
3. Scale Score Writing (WRIT) reached significance, $F(3,791) = 3.205$, $p = .023$, partial $\eta^2 = .012$, observed power = .740, indicating group-related differences.
4. Scale Scores GP and Reading (READ) did not reach significance, suggesting no substantial differences across groups ($p > .05$).

Table 21: ANOVA Results with Bonferroni correction of Rating_Max_group against own NAPLAN scores

Dependent Variable	df	F	Sig.	Partial η²	Observed Power
Scale Score GP	(3, 791)	1.927	.121	.007	.499
Scale Score NMCY	(3, 791)	**6.164**	**<.001**	**.023**	**.963**
Scale Score READ	(3, 791)	1.683	.169	.006	.442
Scale Score SPEL	(3, 791)	**3.777**	**.010**	**.014**	**.815**
Scale Score WRIT	(3, 791)	**3.205**	**.023**	**.012**	**.740**

Note. Significant results ($p < .05$) indicated meaningful differences across groups.

Interpretation

- Numeracy (NMCY) demonstrated the strongest effect across groups ($p < .001$, partial $\eta^2 = .023$).
- Spelling (SPEL) and Writing (WRIT) also showed significant variation, suggesting that performance differed based on the grouping variable.Grammar & Punctuation (GP) and reading (READ) did not reach significance, indicating stability across groups in those domains.

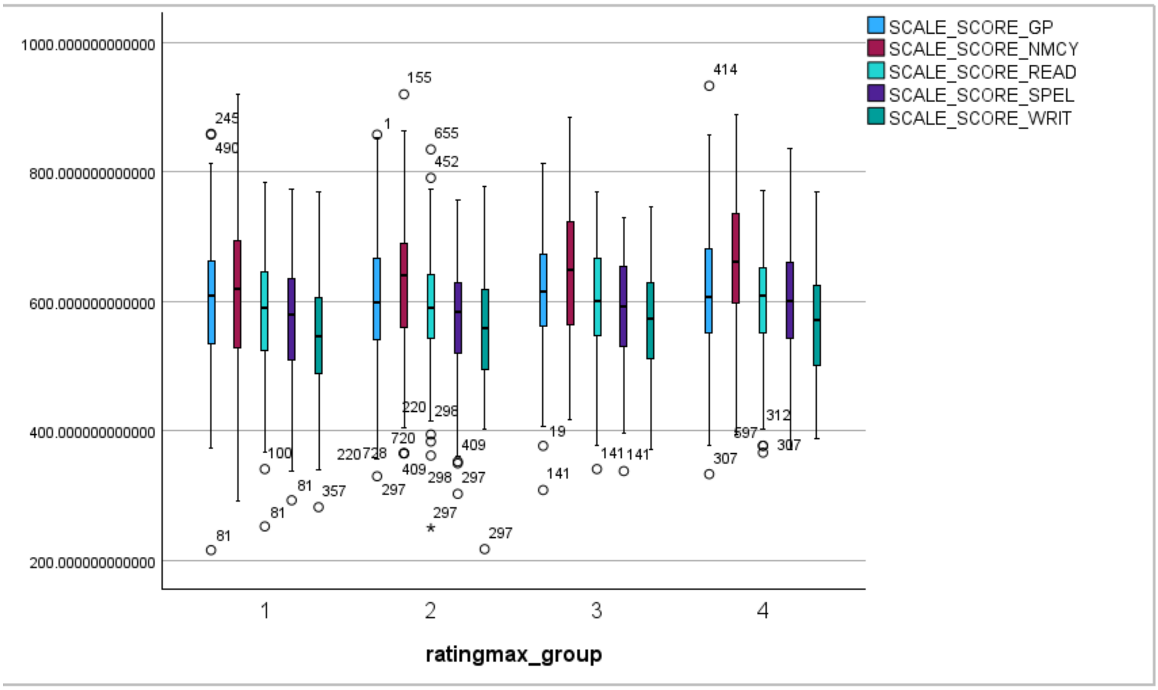


Figure 5: Boxplots for the NAPLAN scale scores disaggregated by the Rating_Max_Group

5.4.3.3 $H2_0$: Chess rated players in school groups do not significantly differ from students' own NAPLAN test results in

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score – WRIT

Results of the MANOVA yielded that there was a statistically significant difference among the three groups on the combined dependent variables, Pillai's Trace=.065, F(10,1572)=5.251,p=.001, partial ŋ2=.032, observed power=1.000 Based on these results, evidence was sufficient to reject the null hypothesis and to conclude that, for the school group, students' combination of the scores on the five tests differed significantly based on the group they were in for their school group rating obtained. The effect size was small. The observed power was 1.000, indicating that there was a 100.0% chance that the results could be shown to be significant.

Based on these results, one-way ANOVAs were conducted. For Scale Score GP, the ANOVA was statistically significant, $F(2,789) = 7.934$, $p < .001$, partial $\eta^2 = .020$, with an observed power of .954. Similarly, Scale Score NMCY demonstrated significant group differences, $F(2,789) = 9.983$, $p < .001$, partial $\eta^2 = .025$, observed power = .985. Scale Score READ was also significant, $F(2,789) = 11.045$, $p < .001$, partial $\eta^2 = .027$, observed power = .992. For Scale Score SPEL, the effect was significant, $F(2,789) = 14.798$, $p < .001$, partial $\eta^2 = .036$, observed power = .999, and finally, Scale Score WRIT was significant as well, $F(2,789) = 18.627$, $p < .001$, partial $\eta^2 = .045$, observed power = 1.000. These results indicated that group differences existed across all tested scale scores.

Table 22: ANOVA results with Bonferroni correction for school groups ($\alpha = .05$)

Dependent Variable	**Degrees of Freedom**	**F**	**p**	**Partial η^2**	**Observed Power**
Scale Score GP	(2, 789)	7.934	< .001	.020	.954
Scale Score NMCY	(2, 789)	9.983	< .001	.025	.985
Scale Score READ	(2, 789)	11.045	< .001	.027	.992
Scale Score SPEL	(2, 789)	14.798	< .001	.036	.999
Scale Score WRIT	(2, 789)	18.627	< .001	.045	1.000

Note. All tests were conducted using the Bonferroni method at an adjusted alpha level of .05. The p-values for all dependent variables were significant at $p < .05$, providing robust evidence against the null hypotheses.

Interpretation

These findings indicated that there were statistically significant differences among groups in Grammar & Punctuation, numeracy, reading, spelling and writing. Although the effect sizes (partial η^2) were small to moderate, the high observed power for each test (ranging from .954 to 1.000) ensured that the analyses were sufficiently sensitive to detect true group differences.

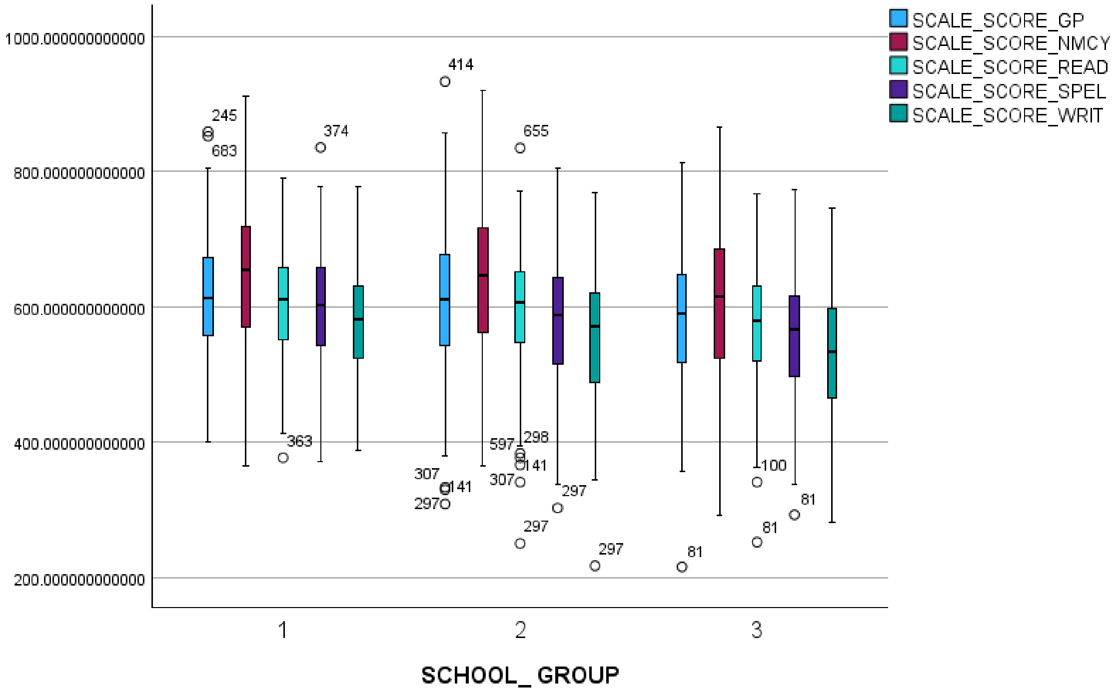


Figure 6: Boxplots for the NAPLAN scale scores disaggregated by school group

5.4.3.4 $H3_0$: Chess rated players in school types do not significantly differ from students' own NAPLAN test results in

f) Scale Score - GP

g) Scale Score - NMCY

h) Scale Score - READ

i) Scale Score - SPEL

j) Scale Score - WRIT

Results of the MANOVA yielded that there was a statistically significant difference among the seven groups on the combined dependent variables, Pillai's Trace=.167, F(30,3925)=4.509,p=<.001, partial ŋ2=.033, observed power=1.000. Based on these results, evidence was sufficient to reject the null hypothesis and to conclude that, for the school type group, students' combination of the scale scores on the five tests differed significantly based on the group they were in for their maximum chess rating obtained. The effect size was small. The observed power was 1.000, indicating that there was a 100.0% chance that the results could be shown to be significant.

Based on the MANOVA, results separate one-way ANOVAs were conducted for the five scale scores: Grammar & Punctuation (GP), Numeracy (NMCY), Reading (READ), Spelling (SPELL) and Writing (WRIT). Using the Bonferroni correction ($\alpha = .01$), the analyses revealed statistically significant differences for each scale score. For example, Scale Score GP, $F(6,785) = 9.923$, $p < .001$, partial $\eta^2 = .070$, and observed power = 1.000, indicating that the groups differed significantly on Grammar & Punctuation. Similar patterns were observed for the remaining variables: numeracy ($F(6,785) = 12.317$, $p < .001$, partial $\eta^2 = .086$, observed power = 1.000); reading ($F(6,785) = 9.515$, $p < .001$, partial $\eta^2 = .068$, observed power = 1.000); spelling ($F(6,785) = 12.077$, $p < .001$, partial $\eta^2 = .085$, observed power = 1.000); and writing ($F(6,785) = 12.862$, $p < .001$, partial $\eta^2 = .090$, observed power = 1.000). These findings, with all p-values well below the adjusted alpha level, provided strong evidence to reject each null hypothesis.

Table 23: ANOVA results with Bonferroni correction for school types ($\alpha = .05$)

Dependent Variable	**Degrees of Freedom**	**F**	**p**	**Partial η^2**	**Observed Power**
Scale Score GP	(6, 785)	9.923	< .001	.070	1.000
Scale Score NMCY	(6, 785)	12.317	< .001	.086	1.000
Scale Score READ	(6, 785)	9.515	< .001	.068	1.000
Scale Score SPELL	(6, 785)	12.077	< .001	.085	1.000
Scale Score WRIT	(6, 785)	12.862	< .001	.090	1.000

Note. All ANOVAs were tested using the Bonferroni correction, with the alpha level adjusted to .01. All p-values were significant at $p < .05$.

Interpretation

These results indicated that there were significant differences among the groups on all five scale scores. Although the effect sizes (partial η^2) ranged from .068 to .090, which were modest in magnitude, the consistently high observed power (1.000 for each test) confirmed that the analyses were well-powered. In sum, the evidence strongly rejected each null hypothesis, supporting the conclusion that group differences existed in Grammar & Punctuation, numeracy, reading, spelling, and writing.

The effect size was small to moderate for all five variables. The strength of relationship between school type and all five variables, whilst significant, was weak to moderate, and together accounted for 39.9% of the variance of the dependent variable. The observed power of 1.000 indicated that there was a 100.0% chance that the results could be shown to be significant for all five variables

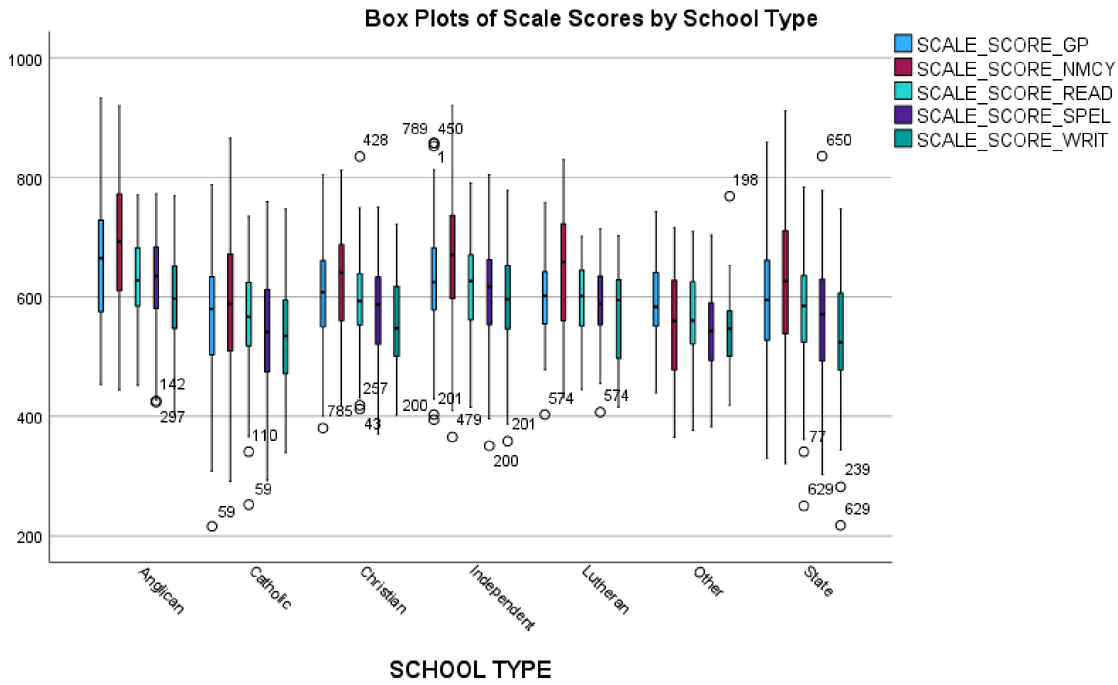


Figure 7: Boxplots for the NAPLAN scale scores disaggregated by School_Type_Group

5.4.3.4 $H4_0$: Chess rated players in LBOTE groups do not significantly differ from students' own NAPLAN test results in

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score - WRIT

Results of the MANOVA yielded that there was a statistically significant difference among the three groups on the combined dependent variables, Pillai's Trace=.065, $F(10,1572)=5.305$, $p= <.001$, partial $Eta^2=.033$, observed power=1.000.

Based on these results, evidence was sufficient to reject the null hypothesis and to conclude that, for the LBOTE group, students' combination of the scale scores on the five tests differed significantly based on the group they were in for their maximum chess rating obtained. The effect size was small. The observed power was 1.000, indicating that there was a 100.0% chance that the results could be shown to be significant.

LBOTE students scored significantly higher in numeracy. Positive findings at a lower level were indicated for spelling and grammar & punctuation.

Table 24: ANOVA results with Bonferroni correction for LBOTE (α = .05)

Dependent Variable	Degrees of Freedom	F	p	Partial η²	Observed Power
Scale Score GP	(2, 789)	5.975	< .003	.015	.880
Scale Score NMCY	(2, 789)	8.650	< .001	.021	.969
Scale Score READ	(2, 789)	0.781	< .458	.002	.183
Scale Score SPELL	(2, 789)	10.615	< .001	.026	.989
Scale Score WRIT	(2, 789)	0.531	< .588	.001	.138

Note. All ANOVAs were tested using the Bonferroni correction, with the alpha level adjusted to .01. p-values were significant for numeracy and writing at p < .05.

Interpretation

The ANOVA results indicated statistically significant group differences on three of the five scale scores: Grammar & Punctuation(GP), Numeracy (NMCY) and Spelling (SPELL). For GP, the difference was significant ($p < .003$) with a small effect size (partial $\eta^2 = .015$) and strong power (.880), suggesting reliable group differences. NMCY showed an even stronger effect ($p < .001$, partial $\eta^2 = .021$, power = .969), while SPELL revealed the largest group difference among the three ($p < .001$, partial $\eta^2 = .026$, power = .989). In contrast, Reading (READ) and Writing (WRIT) scores did not differ significantly across groups, as reflected by non-significant p-values (.458 and .588, respectively), extremely small effect sizes and low observed power, indicating limited sensitivity to detect potential effects.

Overall, meaningful group differences emerged in grammar and punctuation (GP), numeracy and spelling, but not in reading or writing, where the findings suggested caution owing to low statistical power.

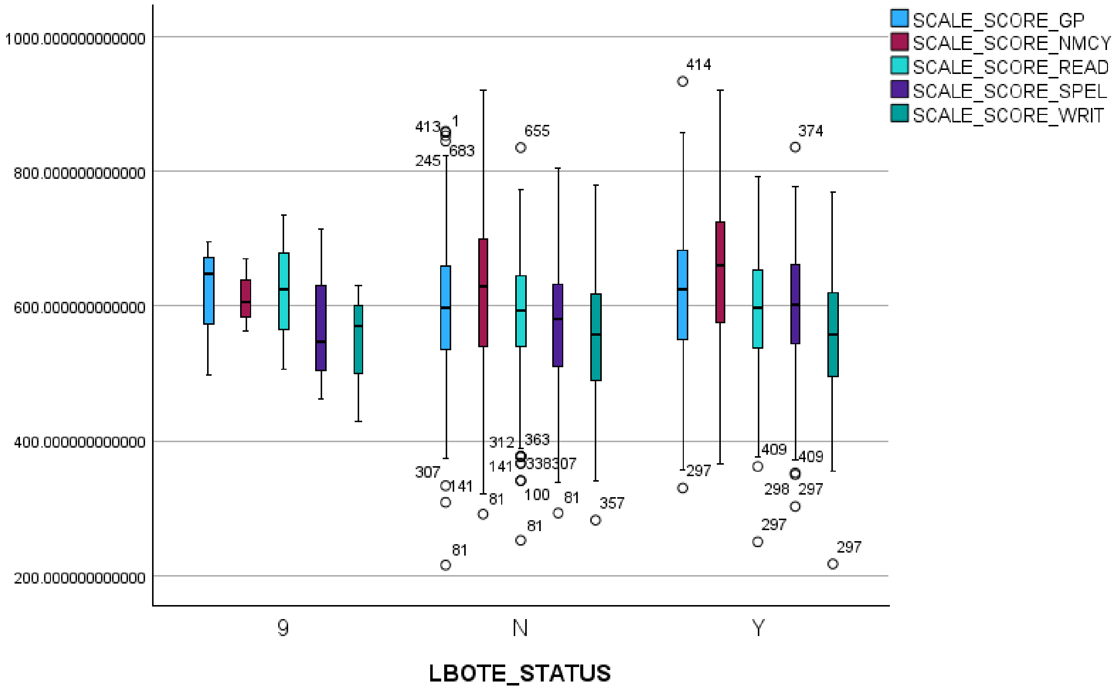


Figure 8: Boxplots for the dependent variables disaggregated by the LBOTE independent variable

5.4.3.5 $H5_0$: Chess rated players in gender groups do not significantly differ from students' own NAPLAN test results in

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score - WRIT

Results of the MANOVA yielded that there was a statistically significant difference between the two groups on the combined dependent variables, Pillai's Trace=.142, $F(5,786)=25.983, p<.001$, partial $\eta^2=.142$, observed power=1.000. Based on these results, evidence was sufficient to reject the null hypothesis and to conclude that, for the gender group, students' combination of the scale scores on the five tests differed significantly. The effect size was small. The observed power was 1.000, indicating that there was a 100.0% chance that the results could be shown to be significant.

Based on the MANOVA results, a series of one-way ANOVAs was conducted to examine the impact of gender on the five dependent scale scores (GP, NMCY, READ, SPEL, WRIT). The Bonferroni correction was applied to maintain a 0.05 significance level ($p < 0.05$) and to control for Type I error.

Key Findings

1. Scale Score GP and Scale Score WRIT showed statistically significant differences ($p < .001$), indicating group effects.
2. Numeracy (NMCY), Reading (READ) and Spelling (SPEL) did not reach the adjusted significance threshold ($p > .01$), meaning their variations across groups were not statistically meaningful.
3. Observed power was highest for GP (.989) and WRIT (.995), suggesting that the results were highly likely to be replicated in a larger sample.
4. Effect sizes (partial η^2) were modest, with GP and WRIT accounting for 4.8% of variance.
5. Males scored higher in numeracy (NMCY), while females outperformed in GP, READ, SPEL and WRIT.
6. Gender comparisons did not yield statistically significant differences, indicating no substantial effect of gender on these scores.

Table 25: ANOVA results with Bonferroni correction for gender (α = .05)

Dependent Variable	df	F	p	Partial η²	Observed Power
Scale Score GP	(1, 790)	**18.047**	**< .001**	**.022**	**.989**
Scale Score NMCY	(1, 790)	6.143	.013	.008	.697
Scale Score READ	(1, 790)	3.902	.049	.005	.505
Scale Score SPEL	(1, 790)	4.767	.029	.006	.587
Scale Score WRIT	(1, 790)	**20.835**	**< .001**	**.026**	**.995**

*Note. Significant results (**p < .05**) indicated meaningful differences across groups.*

Interpretation

The results revealed statistically significant group differences in Grammar & Punctuation (GP) and Writing (WRIT), underscoring the robustness of these findings. In contrast, Numeracy, Reading and Spelling did not surpass strict significance thresholds, pointing to more subtle or inconsistent patterns across groups in these domains. While gender was not a statistically significant factor, observable trends suggested a tendency for males to outperform in numeracy, whereas females demonstrated stronger outcomes in literacy-related areas.

Overall, the effect sizes were small to moderate, indicating that, while the variables examined did influence performance, their impact on scale scores was relatively modest.

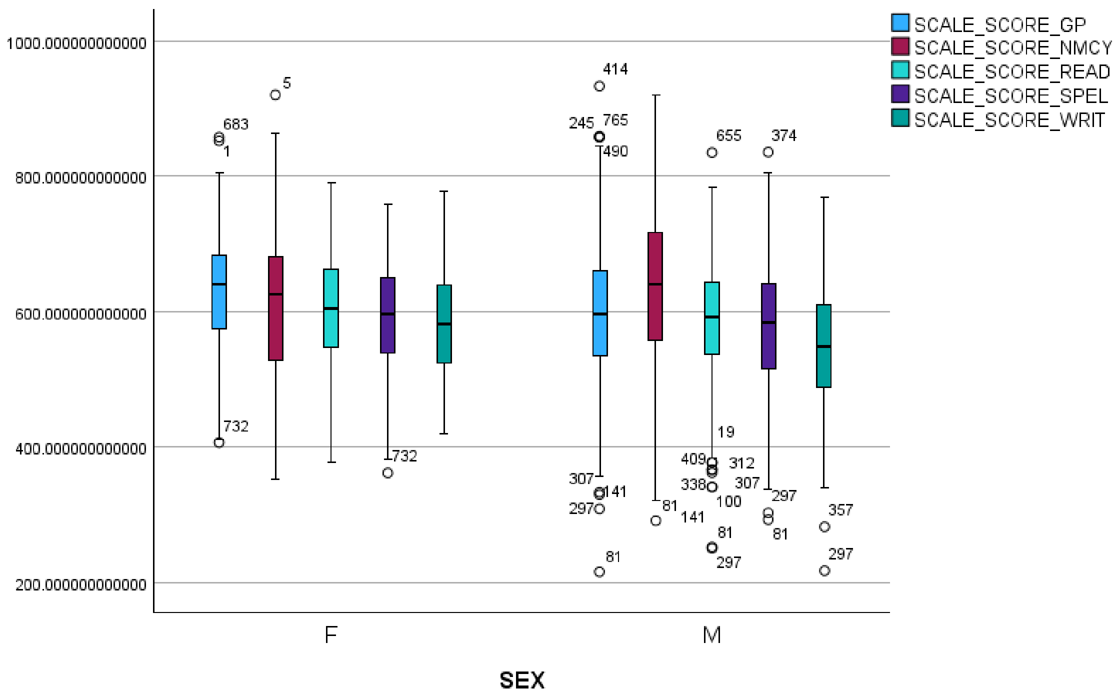


Figure 9: Boxplots for the NAPLAN scale scores disaggregated by GENDER

5.4.3.6 $H6_0$: Chess rated players in school year level groups do not significantly differ from students' own NAPLAN test results in

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score – WRIT

Results of the MANOVA yielded that there was a statistically significant difference among the five groups on the combined dependent variables, $F(18,2319) = 65.328$, $p <.000$, partial $\eta^2 = .336$, with an observed power of 1.000. Based on these results, evidence was sufficient to reject the null hypothesis and to conclude that, for the school year level group, students' combination of the scores on the five tests differed significantly based on the group they were in for their school year level group rating obtained. The effect size was small. The observed power was 1.000, indicating that there was a 100.0% chance that the results could be shown to be significant.

Based on these results, one-way ANOVAs were conducted.

Key findings:

1. Grammar & Punctuation (GP): Significant group differences found, $F(3, 788) = 122.511$, $p < .001$, partial $\eta^2 = .318$, power = 1.000 — large effect size.
2. Numeracy (NMCY): Highly significant, $F(3, 788) = 249.970$, $p < .001$, partial $\eta^2 = .488$, power = 1.000 — very strong effect.
3. Reading (READ): Statistically significant, $F(3, 788) = 178.917$, $p < .001$, partial $\eta^2 = .405$, power = 1.000 — substantial effect.
4. Spelling (SPEL): Significant with largest effect size observed, $F(3, 788) = 253.461$, $p < .001$, partial $\eta^2 = .491$, power = 1.000.
5. Writing (WRIT): Also significant, $F(3, 788) = 215.692$, $p < .001$, partial $\eta^2 = .451$, power = 1.000 — strong group differences.

Table 26: ANOVA results with Bonferroni correction for year level (α = .05)

Dependent Variable	**Degrees of Freedom**	**F**	**p**	**Partial η²**	**Observed Power**
Scale Score GP	(3, 788)	122.511	<.001	0.318	1.000
Scale Score NMCY	(3, 788)	249.970	<.001	0.488	1.000
Scale Score READ	(3, 788)	178.917	<.001	0.405	1.000
Scale Score SPEL	(3, 788)	253.461	<.001	0.491	1.000
Scale Score WRIT	(3, 788)	215.692	<.001	0.451	1.000

*Note. Significant results (**p < .05**) indicated meaningful differences across groups.*

Interpretation

These findings collectively pointed to robust and substantial differences among the groups in all NAPLAN standardised test scores. The results suggested that, whatever factor defined these groups, namely that all groups (year levels) were made up of rated chess players, is strongly associated with student performance across literacy and numeracy measures. Of interest, and aligned with previous ANOVAS reported above, is that the effect sizes for numeracy, spelling and writing were high. Further, that effects increased over time, as illustrated in the boxplot in Figure 10. This would suggest that the longer chess playing students practise and compete, the greater effect this may have on their own test scores.

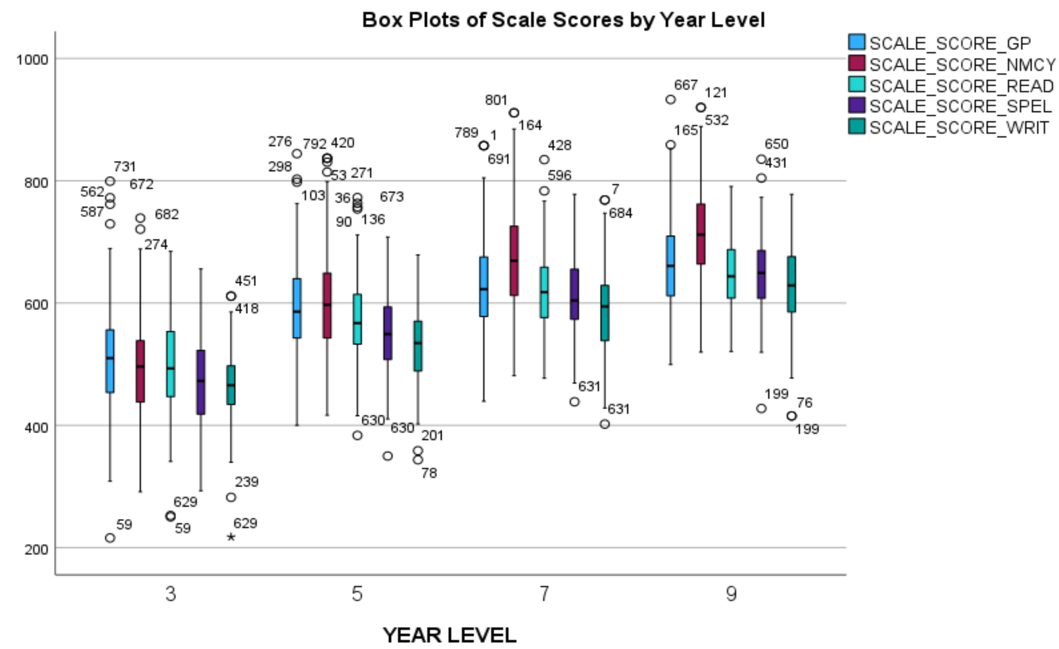


Figure 10: Boxplots for the NAPLAN scale scores disaggregated by YEAR LEVEL

5.4.3.7 $H7_0$: Chess rating groups and school groups do not statistically differ from the Queensland state average NAPLAN test scores in:

a) Diff NAPLAN Score - GP

b) Diff NAPLAN Score - NMCY

c) Diff NAPLAN Score - READ

d) Diff NAPLAN Score - SPEL

e) Diff NAPLAN Score - WRIT

A series of two-tailed independent samples t-tests was conducted to compare the maximum chess ratings groups (Ratingmax_group_1-4) and the high, moderate and low density of rated chess players in schools (School_group_1-3) on five NAPLAN state average scores (diff_NAPLAN_score_Y: Grammar & Punctuation (GP), Numeracy (NMCY), Reading (READ), Spelling (SPEL) and Writing (WRIT)). A significance level of 0.05 ($p < 0.05$) was applied, with the results presented in Table 29 and the findings summarised below.

Key Findings (Significance at $p < .05$):

Rating Max Groups

- Rating Group 1:
  - *Numeracy* (p = .005) – significant under- or over-performance.
- Rating Group 2:
  - *Spelling* (p = .021) – significant difference from the reference score.
- Rating Group 3:
  - No domains reached statistical significance, although *Numeracy* (*p* = .070) and *Writing* (*p* = .071) were marginal.
- Rating Group 4:
  - *Numeracy* (p = .000) and *Spelling* (p = .010) showed significant group differences.

School Groups

- Group 1:
  - *Spelling* (p = .002) and *Writing* (p = .015) were significantly different from the comparison score.
- Group 2:
  - *Numeracy* (p = .020) showed significant variation; Reading was marginal (*p* = .056).
- Group 3:
  - Significant in all domains except *Grammar & Punctuation*, with strong significance in:
    - *Numeracy* (p = .003)
    - *Reading* (p = .018)
    - *Spelling* (p = .011)
    - *Writing* (p = .000)

Table 27: Two-sided T-Test results comparing groups to state average NAPLAN scores

Group	GP (*p*)	NMCY (*p*)	READ (*p*)	SPEL (*p*)	WRIT (*p*)
Rating max group 1	0.726	**0.005**	0.612	0.309	0.106
Rating max group 2	0.084	0.244	0.157	0.021	0.714
Rating max group 3	0.149	0.070	0.223	0.087	0.071
Rating max group 4	0.321	**0.000**	0.359	**0.010**	0.185

Group	GP (*p*)	NMCY (*p*)	READ (*p*)	SPEL (*p*)	WRIT (*p*)
School Group 1	0.756	0.332	0.681	**0.002**	**0.015**
School Group 2	0.140	**0.020**	0.056	0.900	0.201
School Group 3	0.058	**0.003**	**0.018**	**0.011**	**0.000**

Note. Significant results (p < .05) suggested a meaningful positive difference from the state average.

Interpretation

- Numeracy (NMCY) emerged as the most frequently significant domain across groups, particularly within Chess Rating Groups 1 and 4 and all School Groups.
- Spelling (SPEL) and Writing (WRIT) also revealed several significant differences, especially in Ratings Group 4 and School Groups 1 and 3.
- Rating Max Group 3 had *no statistically significant differences* across any domain, suggesting its performance was largely in line with the comparison value.
- School Group 3 demonstrated the most consistent set of significant differences—across four out of five domains, indicating alignment with the state averages with little effect.

5.5 T-Test of H7$_0$: Chess rating groups and school groups do not statistically differ from the Queensland state average NAPLAN test scores in:

Diff NAPLAN Score - GP

Diff NAPLAN Score - NMCY

Diff NAPLAN Score - READ

Diff NAPLAN Score - SPEL

Diff NAPLAN Score – WRIT

Results of the MANOVA yielded that there was a statistically significant difference among the four groups on the combined dependent variables (diff_NAPLAN_Y), Pillai's Trace=.044, *F*(15,2322)=2.298, *p*=.003, partial η^2=.015, observed power=.984. Based on these results, evidence was sufficient to reject the null hypothesis. It can be concluded that, for the maximum rating group, students' average Queensland NAPLAN scores on the five tests differed significantly based on the chess rating group they were in. The effect size was small. The observed power was .984, indicating that there was a 98.4% chance that the results could be shown to be significant.

A series of one-way ANOVAs was conducted to assess differences in Diff NAPLAN Scores (GP, NMCY, READ, SPEL, WRIT) across groups. The Bonferroni correction was applied at an alpha level of 0.05 to control for Type I error.

Key Findings

1. Diff NAPLAN Score NMCY was statistically significant ($p < .001$), indicating significant group differences in numeracy scores.
2. Diff NAPLAN Score SPEL also reached significance ($p = .003$), suggesting meaningful variation in spelling scores.
3. Diff NAPLAN Score GP, READ and WRIT were not statistically significant ($p > .05$), meaning there was insufficient evidence to reject their null hypotheses.
4. Observed power was highest for NMCY (.979) and SPEL (.898), ensuring strong detectability of true effects.
5. Effect sizes (partial η^2) indicated modest group differences, even where significance was observed.

Table 28: ANOVA results with Bonferroni correction for rating groups against the state average NAPLAN scores (α = .05)

Dependent Variable	df	F	p	Partial η²	Observed Power
Diff NAPLAN Score GP	(3, 776)	1.926	.124	.007	.499
Diff NAPLAN Score NMCY	(3, 776)	**6.915**	**< .001**	**.026**	**.979**
Diff NAPLAN Score READ	(3, 776)	1.576	.194	.006	.417
Diff NAPLAN Score SPEL	(3, 776)	**4.722**	**.003**	**.018**	**.898**
Diff NAPLAN Score WRIT	(3, 776)	2.316	.074	.009	.584

*Note. Significant results (**p < .05**) indicated meaningful differences across groups.*

Interpretation

- Numeracy (NMCY) and Spelling (SPEL) showed statistically significant effects, suggesting variation across groups.

- Grammar & Punctuation (GP), Reading (READ) and Writing (WRIT) did not show significant differences, meaning group variations were not strong enough to reject the null hypotheses.
- Effect sizes remained small to moderate, reinforcing the modest influence of group differences on these scale scores.

The observed power of NMCY (.979) and SPEL (.898), which together accounted for 4.4% of the variance of the dependent variables, indicated that there was an 89.8 to 97.9% chance that the results would be observed.

Table 29: Multiple comparisons between ratings groups and state average scores using Tukey HSD

Dependent Variable	Rating Max Group	Mean Diff	Std. Error	Sig	Lower Bound	Upper Bound
diff NAPLAN NMCY	**1,4**	**-31.41**	**7.37**	**<.001**	**-50.38**	**-12.44**
	2,4	**-23.6**	**8.27**	**0.023**	**-44.9**	**-2.3**
diff NAPLAN SPEL	**1,4**	**-17.1**	**5.86**	**0.019**	**-32.18**	**-2.02**
	2,4	**-21.96**	**6.58**	**0.005**	**-38.89**	**-5.02**

Results from the analysis of Rating Max Groups vs diff NAPLAN scores suggested that those students in Group 4 (with the highest chess rating) showed higher diff NAPLAN scores (the difference between their NAPLAN scale score and the state average) than those in both Groups 1 and 2. The difference in Numeracy was greater compared to Group 1 (31.41) than to Group 2 (17.1). The difference in Spelling was closer with Group 1 at 23.6 and to Group 2 at 21.96 below Group 4.

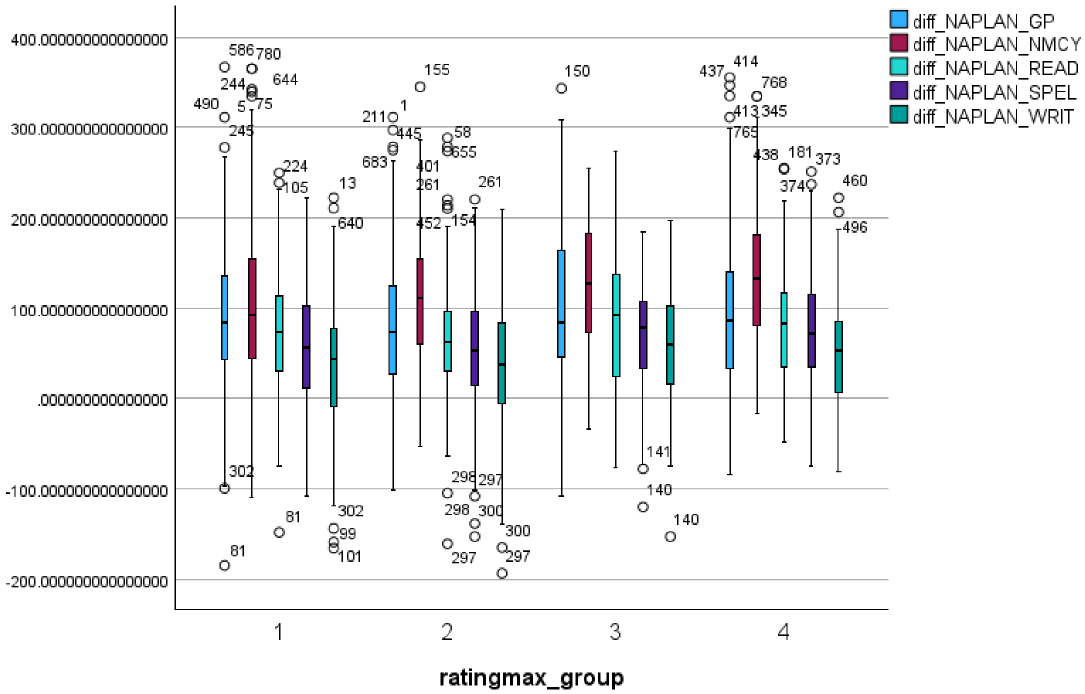


Figure 11: Boxplots for the diff NAPLAN scores disaggregated by the Rating_Max_Group

5.6 Summary of the Hypothesis Tests

$H1_0$ Chess ratings groups do not significantly differ from students' own NAPLAN test results in:

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score - WRIT

MANOVA / ANOVA results

Accepted ($p > 0.05$)

The Anova results accepted the null hypothesis that there were no group differences for:

- Scale Score GP p= .121

- Scale Score READ p=.169

Rejected ($p < 0.05$)

The Anova rejected the null hypothesis that group difference were statistically significant for:

Scale Score NMCY p<.001;

Scale Score SPEL p=.010;

Scale Score WRIT p=.023

For the highly significant NMCY result, Figure 12 illustrates improvement over time (increases in chess ratings by more practising and competing more over time, the better students perform against their own scores).

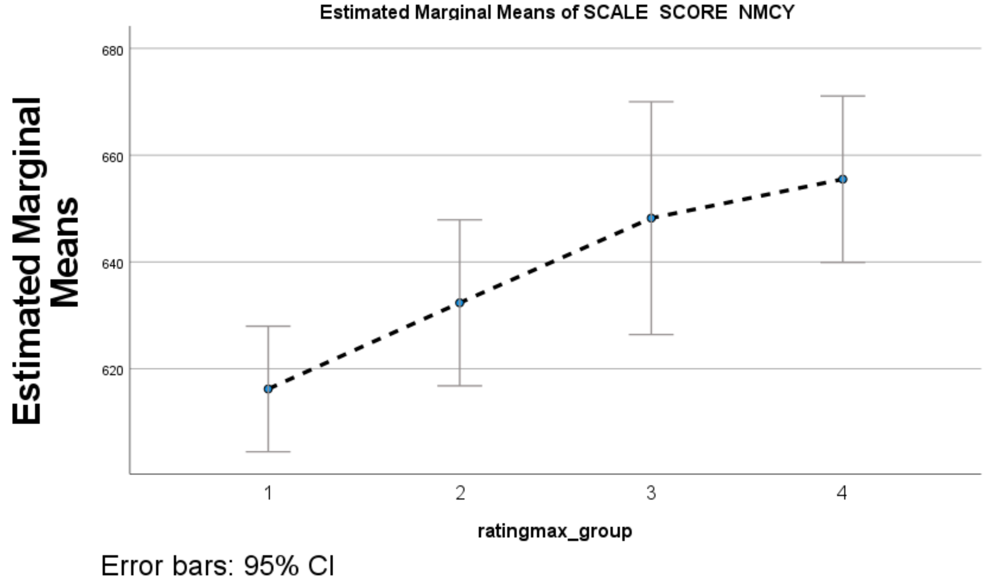


Figure 12: Estimated marginal mean of students in four chess ratings over time

$H2_0$ Chess rated players in School Groups do not significantly differ from students' own NAPLAN test results in:

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score – WRIT

MANOVA / ANOVA results

Accepted ($p > 0.05$)

No Anova results accepted the null hypothesis that no group differences existed.

Rejected ($p < 0.05$)

The Anova results rejected the null hypothesis that group difference were statistically significant for:

Scale Score GP $p<.001$

Scale Score NMCY $p<.001$

Scale Score READ $p<.001$

Scale Score SPEL $p<.001$

Scale Score WRIT $p<.001$

For the highly significant result across all NAPLAN scale scores, Figure 13 illustrates, with a large effect ($n^2 = 0.25$) and very high observed power (0.985), numeracy improvement over time (increases in chess ratings by more practising and competing more over time, the better students perform against their own scores).

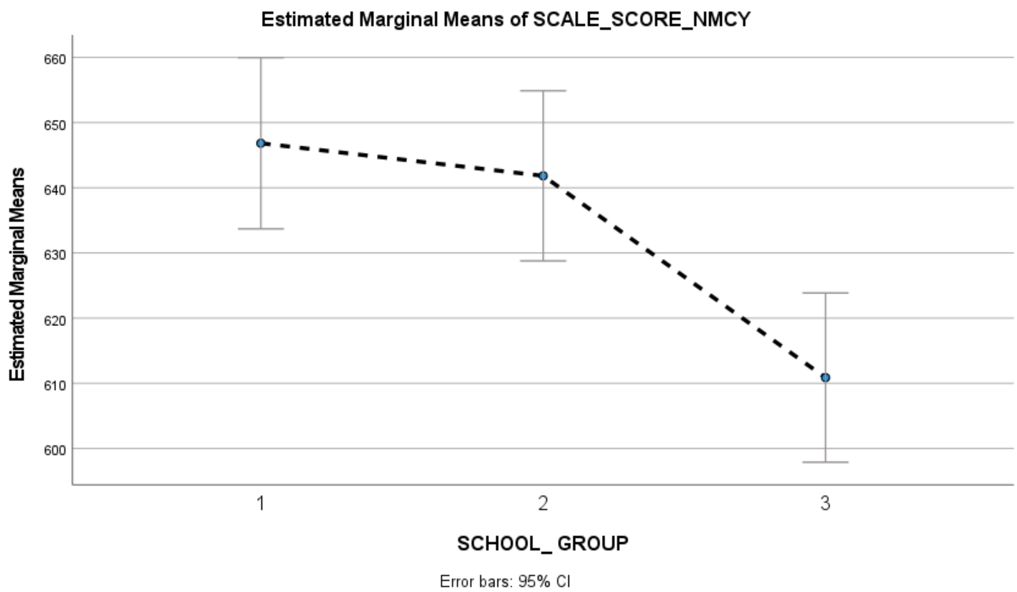


Figure 13: Numeracy NAPLAN scores per school group

$H3_0$ Chess rated players in school types do not significantly differ from students' own NAPLAN test results in Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score - WRIT

MANOVA / ANOVA results

Accepted ($p > 0.05$)

No Anova results accepted the null hypothesis that no group differences existed.

Rejected ($p < 0.05$)

The Anova results rejected the null hypothesis that group difference were statistically significant for:

Scale Score GP $p<.001$

Scale Score NMCY $p<.001$

Scale Score READ $p<.001$

Scale Score SPEL $p<.001$

Scale Score WRIT $p<.001$

$H4_0$ Chess rated players in LBOTE groups do not significantly differ from students' own NAPLAN test results in:

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score - WRIT

MANOVA / ANOVA results

Accepted ($p > 0.05$)

The Anova results accepted the null hypothesis that there was no group differences for:

Scale Score READ p= .458

Scale Score WRIT p= .588

Rejected (< 0.05)

The Anova rejected the null hypothesis that group difference were statistically significant for:

Scale Score GP p= .003

Scale Score NMCY p<.001

Scale Score SPEL p<.001

$H5_0$ Chess rated players in GENDER groups do not significantly differ from students' own NAPLAN test results in:

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score - WRIT

MANOVA / ANOVA results

Accepted (p > 0.05)

No Anova results accepted the null hypothesis that no group differences existed between groups.

Rejected (p < 0.05)

The Anova rejected the null hypothesis that group difference were statistically significant for:

Scale Score GP p= <.001

Scale Score NMCY p= .013

Scale Score READ p= .049

Scale Score SPEL p= .029

Scale Score WRIT p= <.001

$H6_0$ Chess rated players in school Year Level groups do not significantly differ from students' own NAPLAN test results in:

Scale Score - GP

Scale Score - NMCY

Scale Score - READ

Scale Score - SPEL

Scale Score – WRIT

MANOVA / ANOVA results

Accepted ($p > 0.05$)

No Anova results accepted the null hypothesis that no group differences existed.

Rejected ($p < 0.05$)

The Anova rejected the null hypothesis that group difference were statistically significant for:

Scale Score GP $p<.001$

Scale Score NMCY $p<.001$

Scale Score READ $p<.001$

Scale Score SPEL $p<.001$

Scale Score WRIT $p<.001$

$H7_0$ Chess rating groups and school groups do not statistically differ from the Queensland state average NAPLAN test scores in:

Diff NAPLAN Score - GP

Diff NAPLAN Score - NMCY

Diff NAPLAN Score - READ

Diff NAPLAN Score - SPEL

Diff NAPLAN Score – WRIT

MANOVA / ANOVA

Accepted ($p > 0.05$)

The Anova results accepted the null hypothesis that no group differences existed for:

- Diff NAPLAN Score – GP p= .124
- Diff NAPLAN Score – READ p= .194
- Diff NAPLAN Score – WRIT p= .074

Rejected ($p < 0.05$)

The Anova results rejected the null hypothesis that group difference were statistically significant for:

Diff NAPLAN Score – NMCY p<.001
Diff NAPLAN Score – SPEL p=.003

T-Tests

Rejected

• Numeracy (NMCY) emerged as the most frequently significant domain across groups, particularly within Chess Rating Groups 1 and 4 and all School Groups.
• Spelling (SPEL) and Writing (WRIT) also revealed several significant differences, especially in Ratings Group 4 and School Groups 1 and 3.

The null hypothesis was rejected for certain NAPLAN score scales, concluding that there was a statistically significant difference between ratings groups and school groups and the NAPLAN state averages, especially for numeracy and spelling.

5.7 Conclusion

This chapter presented the results of the statistical analysis of the data as per the analysis techniques mentioned in Chapter Four. The design of the analysis followed the guidelines suggested by Hair et al. (2019) for multivariate analysis comparing groups and testing hypotheses. A sequential analysis approach was adopted that: first cleaned and screened the data, then conducted descriptive statistical analysis to familiarise the researcher with the nature and distribution of the data, then correlation analysis to detect the underlying relationships between the data, then MANOVAs including testing for the assumptions required to conduct the analysis with ANOVAs conducted for statistically significant results. Finally, T-tests were conducted for null hypothesis seven. The results of the hypothesis tests were then presented based on the results of the analyses.

Chapter Six presents the responses to the research questions based on the results of the analyses.

CHAPTER 6: RESPONSE TO RESEARCH QUESTIONS AND CONCLUSIONS

6.1 Introduction

The overarching primary research question of the study, which evolved from a stakeholder survey, scoping review and systematic literature review, asked, "Does playing chess as measured by extra practice and competing by Queensland school students have measurable educational benefit in terms of standardised literacy and numeracy test scores?"

This research was primarily motivated by: a) the perceived importance of the concept of "far transfer" related to chess in education; b) papers by Sala and Gobet (2016, 2017a, 2017b, 2017c, 2018) and Blanch (2022) indicating that the existence of "far transfer" is highly unlikely in the case of students learning to play chess; and c) a paper by Poston and Vandenkieboom (2019) that challenged that conclusion, suggesting that students practising and competing in chess (and not simply learning to play), as determined by their chess ratings over time, do show statistically significant improvement, especially in their numeracy standardised test scores.

The importance of "far transfer" when conducting research (especially education) should not be underestimated, as educators generally hope that skills taught in one domain will also be of educational benefit in other domains. This may have been explained best by Perkins and Salomon (1992), who stated that "transfer is a key concept in education and learning theory because most formal education aspires to transfer" (p. 3).

To get to the stage where a meaningful quantitative study could be conducted, it was necessary to gain an extensive understanding of the research in the field of children learning chess and the possible related benefits.

Chapter One provided the background and context of the study. It specified the problem being addressed (i.e., the relationship between students playing chess in schools and the possible educational benefits this may have in terms of standardised test scores). The chapter sought to address the gap in the literature where stakeholders' perceptions of the educational benefits of playing chess were presented. This was deemed important owing to these stakeholders having a far closer relationship to the perceived benefits than that which is reported by researchers, who are generally more distant from the phenomenon. The findings from 315 respondents indicated the strong belief of those involved that, for many reasons, chess has numerous educational benefits for students across three domains: Creativity and Life Skills, Social and Learning Skills, and Thinking Skills.

Chapter Two presented a general overview of the literature generally related to school students and playing chess in school. The chapter outlined numerous lines of enquiry displaying a broad scope of interest in the educational and social benefits of chess. Chapter Three narrowed these lines of enquiry to the literature associated with the effect of school students playing chess and the effect this may have on their standardised test scores, most notably for numeracy and literacy. The chapter then narrowed the scope of the study by presenting a scoping review of papers relating to literacy and numeracy scores, in order to match the standardised testing conducted annually by QCAA. An important finding from the scoping review was that most papers focused on children who were learning to play the game of chess and at the beginner stage of their chess journey. A substantial number of researchers reported some academic benefits for children learning chess. Very few researchers investigated children going beyond the beginner stage, and only one did so substantially. This localised study was conducted by Poston and Vandenkieboom (2019) investigating children learning, practising and competing in chess as determined by their chess rating score over time.

Based on the scoping review, a conceptual model informing this study, research questions and hypotheses were developed. Chapter Four presented the research methodology of the study, which was explanatory and quantitative in nature. The sampling strategy included the matching of a statewide dataset of Queensland literacy and numeracy scores (NAPLAN) and school student chess ratings (QJRL). Multivariate analysis and hypothesis testing were the primary focus of the analysis technique.

Chapter Five presented the results of the analyses and hypothesis tests.

This chapter: i) responds to the research questions based on the hypothesis tests and discusses their implications; ii) presents the limitations of the study; iii) specifies the contributions of the study to practice and the literature; iv) presents a reflexive account by the researcher of his experience and learnings by doing the study; and v) concludes the study.

6.2 Research Question Responses

The statistical results of the study were presented in Chapter Five. The results progressed through the analysis strategy of: a) first screening and cleaning the data to ensure that the dataset was fit for analysis. The data were then observed in relation to descriptive statistics, including means, SD, and skewness and kurtosis statistics. b) The correlations between the study variables were then considered to familiarise the researcher with relational patterns in the data. The analysis then progressed to: c) testing the assumptions related to MANOVA analysis to ensure that further multivariate analysis was feasible. The results of the MANOVAs then informed: d) individual ANOVA analyses for the statistically significant results of the MANOVAs. The chapter concluded with the results of: e) T-Tests for the hypothesis testing for the study's null hypothesis of hypothesis seven associated with the research questions. A discussion of the results in answering the research questions is presented here.

Research Question 1: Is there a statistically significant difference between Queensland chess ratings groups and students' own NAPLAN scale scores?

The results showed that the null hypothesis was rejected for Scale Score NMCY ($p<.001$), Scale Score SPEL ($p=.010$) and Scale Score WRIT ($p=.023$). However, the null hypothesis was accepted for Scale Score GP ($p=.121$) and Scale Score READ ($p=.169$). This suggested that, as students progressed in improving their chess ratings, there was a statistically significant relationship between their ratings and the improvement in their own NAPLAN spelling and writing scores, and particularly their numeracy scores.

Research Question 2: Chess rated players in school groups do not significantly differ from students' own NAPLAN test results.

The results indicated that the null hypothesis was rejected for all five variables (all $p<.001$). This suggested that schools with a higher perceived chess culture (measured by density of student participation) scored significantly higher in all five tests.

Research Question 3: Chess rated players in school types do not significantly differ from students' own NAPLAN test results in scale scores.

The results indicated that the null hypothesis was rejected for all five variables (all $p<.001$). Based on the Box Plots, students from Anglican schools scored highest on a combination of the five scale scores, followed by Independent, State, Catholic, Christian, Lutheran and Other schools, with minor variations between subjects. Score effects were higher for numeracy than for the other four subjects.

Research Question 4: Chess rated players in LBOTE groups do not significantly differ from students' own NAPLAN test results.

The results showed that the null hypothesis was rejected for Scale Score GP $p= .003$, Scale Score NMCY $p<.001$ and Scale Score SPEL $p<.001$. However, the null hypothesis was accepted for Scale Score READ $p= .458$ and Scale Score WRIT $p= .588$. This suggested that students who used a language other than English at home scored higher in numeracy, spelling, and grammar and punctuation. A large proportion of the LBOTE students involved in this study came from China and India, currently the two strongest chess nations in the world.

Research Question 5: Chess rated players in GENDER groups do not significantly differ from students' own NAPLAN test results.

The results showed that the null hypothesis was rejected for Scale Score GP $p= <.001$, Scale Score NMCY $p= .013$, Scale Score READ $p= .049$, Scale Score SPEL $p= .029$ and Scale Score WRIT $p= <.001$. Box plots indicated that males scored higher in numeracy and females scored higher in reading, writing, spelling, and grammar and punctuation. This confirmed the commonly held belief that males tend to score higher in numeracy and females score higher in literacy.

Research Question 6: Chess rated players in school year level groups do not significantly differ from students' own NAPLAN test results.

The results indicated that the null hypothesis was rejected for all five variables (all $p<.001$). This tended to indicate that chess players who reach a chess rating of 1200+ increase their own literacy and numeracy NAPLAN scores throughout their school years.

Research Question 7: Chess rating groups do not statistically differ from the Queensland state average NAPLAN test scores.

The results showed that the null hypothesis was accepted for Diff NAPLAN Score GP $p= .124$, Diff NAPLAN Score READ $p= .194$ and Diff NAPLAN Score WRIT $p= .074$. However, the null hypothesis was rejected for Diff NAPLAN Score NMCY $p<.001$ and Diff NAPLAN Score SPEL $p=.003$. This important finding indicated that chess players in this study improved their NAPLAN scores, especially in numeracy and also spelling, against the state average.

6.3 Summary of Conclusions

Results of the correlations and MANOVAS indicated modest increases in numeracy scores for those students in the study learning, practising and competing in chess who had reached an advanced Queensland Junior Chess rating of 1200+. This important finding, from a relatively small but significant sample, provides evidence that far transfer may be possible for chess players who reach a high level of chess achievement. Because the 255 participants attended a total of 189 schools, this study was more reliable than the Poston and Vandenkieboom (2019) study, which involved students from just one school. Limitations of this study were the relatively small sample size and the lack of randomisation.

There were some other interesting findings from the statistical analysis. While there were positive results from reaching a high level of chess playing ability measured by chess ratings, there were no significant results for chess activity measured by number of rated games played. The study confirmed the commonly held gender belief whereby males scored higher on numeracy and females scored higher on all four literacy tests. The systematic literature review included 16 papers involving gender issues in chess. There is no conclusive evidence that males are stronger chess players than females.

Anglican and independent school types scored higher than the other types of schools. Students from the 39 schools with a perceived higher chess culture scored higher than those from the 150 schools with a perceived lower chess culture.

Interestingly, LBOTE (languages other than English) students scored higher than non-LBOTE students. The LBOTE students were significantly from India and China, the two most powerful chess nations in the world. One possibility is that LBOTE students, being from overseas, are more highly motivated to do well in their school studies and to qualify to attend the best universities.

As noted earlier in this thesis, students who reach a Queensland Junior Chess Rating of 1200+ are likely to have read chess books, played speed chess, used chess databases, had a chess coach and regularly analysed their scoresheets. They are also likely, to some extent, to have engaged in deliberate practice, habit of mind, metacognition, scaffolding, motivation and heuristics. These factors could amount to a 'perfect storm' and help to explain reasons and circumstances where 'far transfer' appears to occur.

The literature indicated that metacognitive skills do not normally develop until around age 12. This might make it harder to find evidence of far transfer for students aged 12 and under. There will always be exceptions. The researcher recalls observing while a strong Grade 3 or 4 (age 8 or 9) player and a strong Grade 11/12 player, both dressed immaculately in school uniforms, left the tournament hall after their game, en route to the analysis room. The two were discussing moves from the game in a very adult manner, with total respect for each other. The younger player was clearly trying to learn and improve his game, and unknowingly his metacognitive skills as well. So was the older player. The fact that 11/12-year-olds have become chess grandmasters must mean that it is highly likely that metacognition can be present well before age 12.

More widely, most schools provide a music programme as well as a range of sporting options alongside academic offerings for students. Since 2000, there has been a steady increase in schools providing chess for students in Queensland and Australia-wide. The results of this study provide an additional argument for schools to provide chess at least as an option for students. Chess, which many regard as a sport, sits neatly between sport and music for all students, but may particularly benefit students with various difficulties or who have simply not found their ‘thing’.

Importantly, the four sections involved in reaching this conclusion – the survey of stakeholders, the scoping review of numeracy and literacy, the extensive systematic literature review of papers relating to children learning chess and a large range of potential benefits, and the analysis of NAPLAN data from participants in this study – provide useful information to those interested in conducting research in the field of chess and education, the “chess in schools” research community and other interested parties.

Overall, the findings from the seven research questions, taken together, indicate positive outcomes for children learning, practising and competing in chess. Furthermore, the findings are statistically significant and consistent across all the statistical measurements.

6.4 Limitations of the Study

Quantitative research utilising multivariate analysis offers robust insights into complex variable relationships. This has certainly been the case with this study, in that multiple independent variables were used to discern whether practising and competing in chess can be ascribed to changes in standardised literacy and numeracy scores, or whether confounding variables such as player intelligence or teacher effects moderate these statistically significant effects. The study was strengthened using longitudinal data that had the player’s chess rating as a constant measurement likely decreasing any teacher effect. However, despite the rigour of the methods used, several inherent limitations merit consideration:

Reliance on Statistical Assumptions. Multivariate techniques are predicated on several statistical assumptions, including multivariate normality, linearity, homoscedasticity and the absence of multicollinearity. Violations of these assumptions can compromise the validity and interpretability of results. The study presented strenuous tests for the assumptions for MANOVA. These were largely met, and any impact on the validity of the findings was minimal.

Sample Size Constraints and Risk of Overfitting. The reliability of multivariate models is highly sensitive to sample size. Excessive inclusion of variables relative to sample size can lead to overfitting, reducing the generalisability of findings and increasing the likelihood of Type I or Type II errors. The sample size of this study was adequate in relation to the number of variables exceeding analysis guidelines. Techniques addressing Type 1 and Type 2 errors were included in the analysis such as Tukey's text and Mahlanobis distance statistics and a range of model fit indices.

Limited Causal Inference. Without experimental or longitudinal designs, multivariate analyses cannot establish causal relationships. Observed associations may be spurious or confounded by unmeasured variables, thereby limiting the scope of inferential claims. The study was longitudinal by nature and included valid measures of the associated independent variables, which were mostly categorial. It is acknowledged that an experimental longitudinal design including a control group would enhance claims of causality. That said, the study conclusions can be said to be rigorous and certain causal relationships can be deduced subject to further validating research.

Complexity of Interpretation. As the number of variables and interactions increases, the interpretive clarity of results diminishes. Researchers may face difficulties in effectively communicating nuanced statistical outcomes, particularly when latent constructs or interaction effects are involved. The study did not control for interaction effects such as teacher effect or other educational interventions that may have confounded the results. The complexity of interactions was apparent, but the study's use of multiple analysis techniques sought to increase the validity of interpretation by comparing the results from different analysis techniques, including MANOVAs, ANOVAs and t-tests.

Measurement and Construct Validity. The robustness of multivariate findings is contingent upon the accuracy and validity of the instruments employed. Poorly operationalised constructs or invalid measurement tools can undermine the credibility of the analysis. This was a prioritised consideration of the study. Most independent variables were categorical and their measurement was very robust according to the sample characteristics. The NAPLAN scores have been validated continuously for more than 10 years, and as such they are also regarded as a robust measurement of literacy and numeracy scores. The chess player ratings are based on internationally validated criteria. However, the study did rely on a core premise that ratings are a valid measurement reflecting ongoing practising and competing in chess. While the latter part (competing) is robust, the assumption of extra practice assumed by higher ratings can be validated only partially in terms of the standard revisiting of games and reflections on documented chess moves.

Lack of Contextual or Experiential Depth. While quantitatively rigorous, multivariate analyses often fail to capture the depth of individual lived experiences or contextual subtleties. As such, they may overlook interpretive dimensions that are critical in fields where social, cultural or psychological factors are salient. This was fully acknowledged by the study. While the study did seek to include perceptions of stakeholders, it recognised that individualised qualitative studies would enhance the insights and conclusions of this study by contextualising individual differences.

Non-Random Sampling. It was not possible to conduct random sampling in this study. This was mitigated to some extent by gaining consents from a representative sample of the chess ability of students through a range of chess ratings. In Queensland, schools chess programmes generally embrace a full range of chess abilities.

Selection Bias. As previously mentioned, to some extent selection was skewed towards students who had left school at the time of gaining consents.

Scope. The study did not have the scope to conduct advanced methods such as in-class comparisons.

6.5 Contributions of the Study

The Doctor of Professional Studies programme is designed to deliver higher degree by research aimed at making an original knowledge contribution to practice. It refers to its contributions being a “triple-dividend” (van der Laan & Neary, 2016), of the study being its primary contribution to practice but also contributions to the literature/theory and the professional development of the researcher. This section presents the original knowledge contributions derived from the study for practice and in addressing gaps in the literature. This is in addition to the papers for publication embedded in the thesis. The contribution to the development of the researcher as practitioner is presented in Section 5.6 (Researcher’s reflections on the study).

Practice

- Stakeholder perceptions have not been reported in the literature. This study presents the findings of an exploratory study of stakeholder perceptions. The results suggest that parents, teachers, coaches and school decision-makers perceive chess in schools as having a broad range of educational benefits. The findings may be of interest in determining whether and to what extent chess in schools should be enabled.
- The results of the study suggest that, as students progressed in improving their chess ratings, there was a statistically significant relationship between their ratings and the improvement in their own NAPLAN spelling and writing scores and particularly in their numeracy scores. This implies that, for schools that wish to include extra-mural activities that are linked to higher spelling, writing and, more specifically, numeracy NAPLAN results, chess is statistically likely to achieve this.
- The results also suggest that schools with a higher perceived chess culture (measured by density of student participation) scored significantly higher in all five tests. It is implied that schools wishing to increase their NAPLAN average scores are likely to achieve this by increasing the number of chess-rated students in their cohorts as a proportion of the total numbers of students.

Literature

- No previous studies have been located that aimed to represent stakeholder perceptions related to chess in schools (parents, teachers, school leaders, coaches). This thesis presents a study and typology of the perceived educational benefits of chess in schools.
- A systematic literature review extends beyond the scope of the study as it relates to children playing chess and the broader reported dimensions of this phenomenon and its social and cognitive benefits.
- The study confirms the argument by Sala and Gobet (2016, 2017a, 2017b, 2017c, 2018) and by Jerrim et al. (2016) that future studies related to learning to play the game of chess at the basic level (Beginner) and its impact on standardised test scores for literacy and numeracy are unwarranted owing to no sign of far transfer taking place.

- The study addresses a gap in the literature related to investigating the impact of prolonged practising and competing in chess over time on standardised test scores for literacy and numeracy.
- The study presents a conceptual model for future research that presents conceptual clarity and the operationalisation of variables to conduct more advanced studies.
- The study provides a large-scale longitudinal research methodology and rigorous sampling and analysis to produce the findings, building on Poston and Vandenkieboom.

6.6 Researcher's Reflections

My interest in chess commenced when I attended lunchtime chess club and represented Windsor Grammar School, UK throughout my senior school years. Prior to commencing my Certificate of Professional Studies, Masters and Doctorate in August 2015, my career was characterised by accounting, professional fundraising, public relations and running a chess centre. I have never studied opening theory in chess and regard myself as an average club player. I had a maximum Australian Chess Federation rating of 1601, and I was President of the Australian Chess Federation from 1999-2003. With my wife Wendy, I owned a chess business, Gardiner Chess, which we commenced in 2003 and sold in December 2015 upon my retirement.

Reflections

Longevity: Several years ago, I fell asleep at my computer while studying and landed on my head, leading to hospitalisation. Since then, I have always spent my entire studying time standing up with a raised desktop. I recommend it. Also, at age 77, I still ride my bike three times a week with my mates (excellent for minimising study, or any other, worries, and health generally).

Much of my time in business was spent dealing with day-to-day challenges and solving problems, with less time for planning, especially long-term planning. All was outcome-based. Time for reflection was minimal.

For each of my certificate, masters and doctor of professional studies, I provided learning objectives as follows:

Certificate of Professional Studies:

- Gain a solid understanding of the concept of tolerance for ambiguity
- Enhance analytical and critical thinking skills
- Increase overall industry knowledge

Masters:

- Conduct relevant literature searches, critically evaluate theories and analyse data
- Increase professional knowledge and communication skills by acquiring academic writing skills
- Improve critical judgement skills

Doctorate:

- Develop objective judgement by assimilating and evaluating literature
- Develop an increased tolerance for ambiguity
- Advance systemised information gathering skills

Reflecting on these nine outcomes:

For two of the nine in particular, I could have done better:

Advanced systemised information gathering skills – my impression is that I improved but did not efficiently learn to use all the technology or systems available. I regret not allocating more time to getting the most out of the available technology. It would have saved time in the long run.

Increase professional knowledge and communication skills by acquiring academic writing skills – I did a lot of reading, plenty of writing, lots of corrections and lots of iterations. However, I regard my academic writing skills as passable, no more. For the other seven, I'm reasonably comfortable with my improvement.

Tolerance for ambiguity – I've learned to expect changes to everything I write – nothing is sacred. I question everything. I endeavour to define everything very carefully. I expect to be out of my comfort zone, which has been a very common occurrence. But I try always to embrace new challenges.

Critical thinking skills – I quickly learned that not much is simple in academia. There is a need to understand each problem deeply and not to make instant judgements. Read as much as is necessary and discuss with self.

Industry knowledge – this is critical for definitions of variables. I endeavour to understand what is important about the applicable industry and understand the key factors. What can be measured, and how? Having been deeply involved in the "chess in schools" sector, I found this information critical.

Conducting relevant literature searches, critical evaluation of theories and analysing data – I was never happier during the entire study process than when searching, recording and categorising all the relevant studies in EndNote. This was particularly true when searching and reading to find important and relevant information whilst building, revising or refuting a theory.

Develop objective judgement by assimilating and evaluating literature – this follows on naturally from the preceding paragraph – and it follows that I would never tire of following up lines of enquiry.

Improve critical judgement skills – learning not to jump to conclusions and to deep dive into subject matter. Too often, it is easy to take something at face value and to suffer the inevitable consequences, which happened often.

Enhance analytical and critical thinking skills – Having had very little previous experience with statistics was highly challenging, but nevertheless, endeavouring to understand and report on these skills was ultimately beneficial.

Experiences at our chess centre with children with various difficulties gave the strong impression that chess was highly beneficial for many of these students, particularly those with various forms of autism, and one who was completely blind (eyesight impaired). Conversations with parents corroborated these impressions. Unfortunately, children with these difficulties could not be tagged for this study.

My final personal remarks relate to the Professional Studies programme, of which I was a part and which was recently discontinued. In my opinion, this is a programme that can have significant ongoing benefits for society. Most participants are still pursuing their career when they take part. Obtaining a higher degree by research can contribute to promotion. Each participant is endeavouring to solve or facilitate a workplace situation or task. In my case, I have succeeded in providing useful information to chess in schools stakeholders – i.e., parents, teachers, chess coaches, student participants, those involved in “chess in schools” theory, those interested in the concept of “far transfer” and educators in general. In other cases, participants invariably provide useful information for both their institution and society.

6.7 Suggestions for Future Research

The conclusions and limitations of the study having been considered, the following suggestions for future research are proposed in relation to chess in schools and its effect on standardised literacy and numeracy scores.

- Utilise the conceptual model, or variations thereof depending on context, to capture the effect of prolonged practising and competing in chess on standardised test scores.
- Explore further lines of enquiry that link practising and competing in chess with other cognitive abilities and thinking capabilities such as creativity, analytical thinking, strategic thinking, conceptual thinking, etc.
- Strengthen testing of statistical assumptions through enhanced diagnostics. Although the present study diligently assessed assumptions for MANOVA, future research should consider integrating more robust diagnostics, including nonparametric alternatives and resampling techniques (e.g., bootstrapping) when assumption violations are borderline. This would reinforce the reliability of the findings, particularly in complex multivariate studies.
- Increase sample size relative to model complexity. To mitigate risks of overfitting further and to enhance generalisability, subsequent studies should aim to increase the sample size proportionally to the number of predictors included in multivariate models. While this study met guidelines for sample size, it would be important to increase the sample of the number of chess-rated players to include the majority of the 15000 students and former students in the QJRL.
- Similarly to the current study design, future studies should enhance the experimental longitudinal research design, including the incorporation of interaction terms and advanced multivariate modelling (such as regression analysis, structural equation modelling or partial least squares techniques).

This would substantially bolster claims of causality and help disentangle complex confounding influences.

- Accounts of the lived experience of school aged chess players relating to practising and competing in chess and the effects of doing so are non-existent in the literature. In addition to building on the stakeholder perceptions study incorporated in this thesis, future studies should incorporate qualitative approaches for contextual depth to enhance interpretive nuance and face validity. Interviews, case studies or narrative analyses could uncover subjective dimensions of experience that may otherwise remain obscured in multivariate statistical approaches. Encouragingly, the advanced regressions conducted by second supervisor Dr Smerdon using additional data obtained from the Australian Curriculum, Assessment and Reporting Authority (ACARA) for the same dataset on which this research was based indicated statistically significant causal findings for improved numeracy scores between Grades Three and Nine for advanced chess players. Dr Smerdon eliminated possible confounding factors. These findings have further positive implications for the theory of “far transfer”, and it is intended that they be published in due course.

6.8 Conclusion

Empirically, this thesis demonstrates the importance and extent of chess research in education and society. The systematic literature review has revealed an interesting development. Chess is no longer just the subject, but also now a significant tool for research in other fields, especially AI. At the time of completing this thesis, the appearance of papers involving chess and AI seems to be increasing dramatically.

Earlier in this thesis, the author declared that he owned a “chess in schools business” and was involved in the “chess in schools” scene in Queensland from 1990-2015. This study was based on a study by Poston and Vandenkieboom (2019). They described a chess scene very similar to that experienced by this author. Vandenkieboom was the curriculum organiser for schools in the Los Alamos district of New Mexico. In her position, she was presumably involved in their research because she was interested in seeing if chess helped academic scores. Perhaps she

and Poston, who at the time was the leader of the Compact Fission Reactor Design Team at Los Alamos National Laboratory, had children involved in chess.
Both their research and this study produced outcomes that suggest that chess is possibly related to improved literacy and numeracy outcomes for participating students. The main difference between the two studies is that the Los Alamos study was in just one school, whilst the Queensland study involved collecting data from 189 schools. Currently, this study has indicated that there has been a substantial increase in “chess in schools” programmes in Queensland and Australia. FIDE chess in schools research suggests that this is happening in many countries around the world, including India and China.

It is quite possible that schools involve chess in their school offerings for simple reasons. For example, many students just love the game, but there is more to it than that. At interschool chess tournaments, children learn to shake hands before and after the game, and it is obvious that students have their heads between their hands, concentrating deeply. At the very least, good manners and concentration would be good outcomes for young chess players and are immediately apparent to educators.

Schools, teachers, parents and “chess in schools” businesses are always looking to see if there are benefits for students in terms of academic outcomes. From the extensive literature reviews included in this study, it is becoming clearer that merely learning to play chess at a very basic level is highly unlikely to have any benefits for students in terms of academic scores. However, although Gobet and Sala (2016, 2017a, 2017b, 2017c, 2018) believe it is highly unlikely that learning chess has any benefits for children in terms of academic scores, this study has shown that benefits are entirely possible for students taking their chess playing ability to a more advanced level.

These findings may encourage some educators who are not quite sure whether it is a good idea to have a chess programme in their school to think again. The results may also be an encouragement for “chess in schools” businesses to expand their operations.

There were other important takeouts from the systematic literature review. There was a significant number of studies relating to people who face some kind of special challenge to cope with or overcome. Chess must be one of the few activities, sporting or other, that lends itself to everyone, including all those with any kind of special needs, disadvantages, disability, difficulty or psychological problem. Everyone can aspire to compete individually or in a team at every level of world chess. Equally, people can simply play chess to enjoy everything about the challenges, and even the aesthetics, that it offers. It appears that this field is ripe for significantly more research.

The systematic literature review includes many papers that examine gender issues in chess. For many years, it was believed that males were better than females at chess. Now researchers are uncertain. The quantitative part of this study added to the growing evidence that males are better at numeracy and females are better at literacy.

In the 1990s, junior interschool and individual chess competitions in Australia almost entirely featured students with an Anglo-Saxon background. This can be shown when looking back through the records. At a recent Australian Under 8 championship, which included nearly 90 players, over 90% had Chinese sounding names. In the current study, 34% were LBOTE students, the majority of whom were from a Chinese or Indian background. Both these countries clearly value chess, as they have vast chess programmes and are rated one and two in the world of serious adult chess. In countries like India and China, with many people existing below the poverty line, chess is very popular because it is cheap to play.

The relatively small sample size of this study (255) encourages further research, possibly through a research grant, preferably on the entire QJRL database (currently approximately 15,000 players). It would be particularly helpful for further research with anonymised data that children with various difficulties be identified, as many of these children were identified in both the “survey of stakeholders” paper and the systematic literature review as benefitting significantly from learning chess. Any research involving chess should especially consider tagging those with ADHD, learning, financial or any other difficulties as these are highlighted in contemporary studies as posing significant challenges to education.

References

Aciego, R., García, L., & Betancort, M. (2012). The benefits of chess for the intellectual and social-emotional enrichment in schoolchildren. *The Spanish Journal of Psychology, 15*(02), 551-559. https://doi.org/10.5209/rev_SJOP.2012.v15.n2.38866

Aciego, R., Garcia, L., & Betancort, M. (2016). Efectos del método de entrenamiento en ajedrez, entrenamiento táctico versus formación integral, en las competencias cognitivas y sociopersonales de los escolares [Effects of chess training method, comprehensive training versus tactical training in cognitive and socio-emotional competences of schoolchildren]. *Universitas Psychologica, 15*(1), 165-176. https://doi.org/10.11144/Javeriana.upsy15-1.emea

Adey, P., Robertson, A., & Venville, G. (2001). *Let's think! A programme for developing thinking in five and six year olds: Teacher's guide.* The NFER-NELSON Publishing Company Ltd.

Adhikari, A., Gorain, S. C., Gayen, P., Pal, I., & Sen, S. (2023). Studying the differences: A review on t-test. *International Research Journal of Education and Technology, 5*(5), 338-349. https://www.irjweb.com/Studying%20the%20Differences%20%20A%20Review%20on%20tTest.pdf

Ahmed, S., & Siddique, M. A. (2017). Playing chess game: Cognitive function and behavioral skill Enrichment. *Global Journal for Research Analysis, 6*(5). https://www.doi.org/10.36106/gjra

Ahrens, A., Zascerinska, J., Bikova, A., Aleksejeva, L., Zascerinskis, M., Gukovica, O., & Abjalkiene, I. (2024). Chess play as a means of improving inclusiveness of disadvantaged groups. *Education. Innovation. Diversity., 1*(8), 134-142. https://doi.org/10.17770/eid2024.1.7928

Alexander, J. M., Carr, M., & Schwanenflugel, P. J. (1995). Development of metacognition in gifted children: Directions for future research. *Developmental Review, 15*(1), 1-37. https://doi.org/10.1006/drev.1995.1001

Anbarci, N., & Ismail, M. S. (2024). AI-powered mechanisms as judges: Breaking ties in chess. *PloS One, 19*(11), e0305905. https://doi.org/10.1371/journal.pone.0305905

Armbruster, B. B., Echols, C. H., & Brown, A. L. (1983). *The role of metacognition in reading to learn: A developmental perspective (Reading education report no. 40).* Center for the Study of Reading, University of Illinois .

Arnold, S. H., Bailey, A. H., Ma, W. J., Shahade, J., & Cimpian, A. (2024). Checking gender bias: Parents and mentors perceive less chess potential in girls. *Journal of Experimental Psychology: General, 153*(1), 1-14. https://doi.org/10.1037/xge0001466

Arraez Infantes, L. (2019). *The Transfer of Chess in Cognitive Abilities and Sociopersonal Abilities in Secondary Education Students. A Theoretical Review la transferencia del ajedrez en las capacidades cognitivas y* *habilidades sociopersonales en alumnos de educación secundaria: Una revisión teórica [The transfer of chess in cognitive abilities and sociopersonal abilities in secondary education students: A theoretical review* [Bachelor's dissertation, Universidad de La Laguna]. http://riull.ull.es/xmlui/handle/915/16225

Asghari, M., Kiyani, R., & Ghahramani, M. (2024). Effectiveness of mindfulness exercises on theory of mind in tee chess girls. *Sports Psychology, 16*(1), 190-204. https://doi.org/10.48308/mbsp.2022.227058.1114

Atashafrouz, A. (2019). The effectiveness of chess on problem-solving, working memory, and concentration of male high school students. *Iranian Evolutionary and Educational Psychology Journal, 1*(4), 249-259. https://doi.org/10.29252/ieepj.1.4.2

August, L. (2024). *A few-shot embedding learning approach for predicting the behavior of individual chess players* [Bachelor's project, University of Groningen]. https://fse.studenttheses.ub.rug.nl/34065/1/BP-Lennart-August-s4800036.pdf

Aydin, M. (2015). Examining the impact of chess instruction for the visual impairment on Mathematics. *Educational Research and Reviews, 10*(7), 907-911. https://doi.org/10.5897/ERR2014.1967

Azevedo, R. (2008). The role of self-regulated learning about science with hypermedia. In D. H. Robinson & G. Schraw (Eds.), *Recent innovations in educational technology that facilitate student learning* (pp. 127-156). Information Age Publishing.

Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition – implications for the design of computer-based scaffolds. *Instructional Science, 33*, 367-379. https://doi.org/10.1007/s11251-005-1272-9

Baasanjav, U. B. (2017). "A girl move": Negotiating gender and technology in chess online and offline. In J. Prescott (Ed.), Handbook of research on race, gender, and the fight for equality (pp. 198-211). IGI Global Scientific Publishing.

Backus, P., Cubel, M., Guid, M., Sánchez-Pagés, S., & López Mañas, E. (2023). Gender, competition, and performance: Evidence from chess players. *Quantitative Economics, 14*(1), 349-380. https://doi.org/10.3982/QE1404

Bailey, R. (2002). Playing social chess: Children's play and social intelligence. *Early Years: An International Journal of Research and Development, 22*(2), 163-173. https://www.tandfonline.com/doi/abs/10.1080/09575140220151495

Balagué i Canadell, J., Barceló-Soler, A., Saurina Canals, C., Solé, S., Demarzo, M., Rivero, F., & Coromina, L. (2023). Mindfulness y autocompasión en la preparación mental de los jugadores de ajedrez [Mindfulness and self-compassion in mental preparation of chess players]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 23*(91), 406- 425. https://doi.org/10.15366/rimcafd2023.91.025

Balata, J., Mikovec, Z., & Slavik, P. (2015). Problems of blind chess players. In *2015 6th IEEE international conference on cognitive infocommunications*

(CogInfoCom), Gyor, Hungary, 2015 (pp. 179-183). https://doi.org/10.1109/CogInfoCom.2015.7390587

Bannert, M. (2006). Effects of reflection prompts when learning with hypermedia. *Journal of Educational Computing Research, 35*(4), 359-375. https://doi.org/10.2190/94V6-R58H-3367-G388

Bannert, M., Hildebrand, M., & Mengelkamp, C. (2009). Effects of a metacognitive support device in learning environments. *Computers in Human Behavior, 25*(4), 829-835. https://doi.org/10.1016/j.chb.2008.07.002

Barbaranelli, C., Caprara, G. V., Rabasca, A., & Pastorelli, C. (2003). A questionnaire for measuring the Big Five in late childhood. *Personality and Individual Differences, 34*(4), 645-664. https://doi.org/10.1016/S0191-8869(02)00051-X

Barbier, A. (2020). *Gender in chess: A mixed-method approach* [Masters dissertation, University of Gent]. https://libstore.ugent.be/fulltxt/RUG01/002/862/596/RUG01-002862596_2020_0001_AC.pdfBarr, N. (2024). *An analysis of expertise-induced amnesia: Semantic and episodic recall of chess moves across different skill levels and conditions* [Masters dissertation, Massey University]. https://mro.massey.ac.nz/server/api/core/bitstreams/e2fe5ad6-4ced-402d-8e26-0f3fc5a56a80/content

Barrett, D. C., & Fish, W. W. (2011). Our move: Using chess to improve math achievement for students who receive special education services. *International Journal of Special Education, 26*(3), 181-193. https://files.eric.ed.gov/fulltext/EJ959011.pdf

Bart, W. M. (2014). On the effect of chess training on scholastic achievement. *Frontiers in Psychology, 5*, 201-203. Https://doi.org/10.3389/fpsyg.2014.00762

Basson, M. R. (2015). *Effects of chess instruction on the intellectual development of grade R learners* [Masters dissertation, University of South Africa]. https://uir.unisa.ac.za/items/51978531-b4ed-4eed-8a75-058614902e30

Belenky, D. M., & Nokes-Malach, T. J. (2012). Motivation and transfer: The role of mastery-approach goals in preparation for future learning. *Journal of the Learning Sciences, 21*(3), 399-432. https://doi.org/10.1080/10508406.2011.651232

Belova, O. (2018). Chess is the method of development of logical thinking in of preschool and primary school children. *Современные научные исследования и разработки, 1*(11), 20-22. https://www.elibrary.ru/item.asp?id=36810600

Berg, A. (2020). Statistical analysis of the Elo rating system in chess. *Chance, 33*(3), 31-38. https://doi.org/10.1080/09332480.2020.1820249

Berk, L. E. (2003). *Child development* (6th ed.). Allyn and Bacon.

Berkley, D. K. (2012). The impact of chess instruction on the critical thinking ability and mathematical achievement of developmental mathematics students. https://usmaimsu.primo.exlibrisgroup.com/permalink/01USMAI_MSU/jong90/alma9963860459308251

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641-1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Bilalić, M., Graf, M., & Vaci, N. (2024). Computers and chess masters: The role of AI in transforming elite human performance. *British Journal of Psychology*. https://doi.org/10.1111/bjop.12750

Bilalić, M., Langner, R., Erb, M., & Grodd, W. (2010). Mechanisms and neural basis of object and pattern recognition: A study with chess experts. *Journal of Experimental Psychology: General, 139*(4), 728-742. https://psycnet.apa.org/doi/10.1037/a0020756

Bilalić, M., McLeod, P., & Gobet, F. (2007). Does chess need intelligence? — A study with young chess players. *Intelligence, 35*(5), 457-470. http://dx.doi.org/10.1016/j.intell.2006.09.005

Bilalić, M., McLeod, P., & Gobet, F. (2009a). Specialization effect and its influence on memory and problem solving in expert chess players. *Cognitive Science, 33*(6), 1117-1143. https://doi.org/10.1111/j.1551-6709.2009.01030.x

Bilalić, M., Smallbone, K., McLeod, P., & Gobet, F. (2009b). Why are (the best) women so good at chess? Participation rates and gender differences in intellectual domains. *Proceedings of the Royal Society B: Biological Sciences, 276*(1659), 1161-1165. https://doi.org/10.1098/rspb.2008.1576

Blanch, A. (2022). Chess instruction improves cognitive abilities and academic performance: Real effects or wishful thinking? *Educational Psychology Review, 34*, 1371-1398. https://doi.org/10.1007/s10648-022-09670-9

Blanch, A., Aluja, A., & Cornadó, M.-P. (2015). Sex differences in chess performance: Analyzing participation rates, age, and practice in chess tournaments. *Personality and Individual differences, 86*, 117-121. https://doi.org/10.1016/j.paid.2015.06.004

Blanch, A., & Colom, R. (2023). *Talent, practice, and excellence: Dominance of nature over nurture in worldwide chess players* [Unpublished paper]. https://osf.io/u82za/download

Blasco-Fontecilla, H., Gonzalez-Perez, M., Garcia-Lopez, R., Poza-Cano, B., Perez-Moreno, M. R., de Leon-Martinez, V., & Otero-Perez, J. (2016). Efficacy of chess training for the treatment of ADHD: A prospective, open label study. *Revista de Psiquiatría y Salud Mental (English Edition), 9*(1), 13-21. https://doi.org/10.1016/j.rpsmen.2016.01.003

Bornstein, J., & Cunningham, C. (2023). Checking for the benefits of chess for people with Autism Spectrum Disorder (ASD). *Journal of Student Research, 12*(3). https://doi.org/10.47611/jsrhs.v12i3.4688

Bouacida, E., Foucart, R., & Jalloul, M. (2024). When expert advice fails to reduce the productivity gap: Experimental evidence from chess players. *Recherche Data Gouv, 4.* https://doi.org/10.57745/UL502I

Brancaccio, A., & Gobet, F. (2023). Scientific explanations of the performance gender gap in chess and science, technology, engineering and mathematics (STEM). *Journal of Expertise, 6*(1), 75-101. https://www.journalofexpertise.org/articles/volume6_issue1/JoE_6_1/JoE_6_1_Brancaccio_Gobet.pdf

Brito, A. R. C. (2021). Efectos del ajedrez en el rendimiento académico, creatividad y memoria general en estudiantes adolescents [Bachelor's dissertation., Universidad de Cuenca, Ecuador]. . https://dspace.ucuenca.edu.ec/items/af7d1ef3-ea93-4328-939d-be404f5def6f

Brusamolin, V., & Pedroni, R. S. (2024). Promoting competencies of the Brazilian common national curriculum with chess. *Main Issues of Pedagogy and Psychology, 11*(2), 208-217. https://doi.org/10.24234/miopap.v11i2.33

Bühren, C., & Frank, B. (2012). *Chess players' performance beyond 64 squares: A case study on the limitations of cognitive abilities transfer*. MAGKS Joint Discussion Paper Series in Economics, No. 19-2010. Universität Marburg. https://www.uni-marburg.de/en/fb02/research-groups/economics/macroeconomics/research/magks-joint-discussion-papers-in-economics/papers/2010-papers/19-2010_buhren.pdf

Burgoyne, A. P., Nye, C. D., Macnamara, B. N., Charness, N., & Hambrick, D. Z. (2019). The impact of domain-specific experience on chess skill: Reanalysis of a key study. *The American Journal of Psychology, 132*(1), 27-38. https://doi.org/10.5406/amerjpsyc.132.1.0027

Burgoyne, A. P., Sala, G., Gobet, F., Macnamara, B. N., Campitelli, G., & Hambrick, D. Z. (2016). The relationship between cognitive ability and chess skill: A comprehensive meta-analysis. *Intelligence, 59*, 72-83. https://doi.org/10.1016/j.intell.2016.08.002

Burján, A. M. (2017). The effects of chess education on mathematical problem solving performance. *Teaching Mathematics and Computer Science, 14*, 153-168. https://doi.org/10.5485/TMCS.2016.0421

Byrd, E. T., Bosley, H. E., & Dronberger, M. G. (2009). Comparisons of stakeholder perceptions of tourism impacts in rural eastern North Carolina. *Tourism Management, 30*(5), 693-703. https://doi.org/10.5485/TMCS.2016.0421

Cabot Thibault, J. (2013). *L'effet de l'apprentissage du jeu d'échecs dans le cadre scolaire sur le développement du sens spatial d'élèves du premier cycle du secondaire* [Doctoral dissertation, Université du Québec à Rimouski]. https://semaphore.uqar.ca/id/eprint/939/

Campione, J. C., Brown, A. L., & Ferrara, R. A. (1982). Mental retardation and intelligence. In R. J. Sternberg (Ed.), *Handbook of human intelligence* (pp. 392-490). Cambridge University Press.

Campitelli, G. (2017). Cognitive processes in chess. In D. Z. Hambrick, G. Campitelli, & B. N. Macnamara (Eds.), *The science of expertise: Behavioral, neural, and genetic approaches to complex skill* (pp. 31-46). Routledge.

Campitelli, G., & Gobet, F. (2005). The mind's eye in blindfold chess. *European Journal of Cognitive Psychology, 17*(1), 23-45. https://doi.org/10.1080/09541440340000349

Campitelli, G., & Gobet, F. (2008). The role of practice in chess: A longitudinal study. *Learning and Individual Differences, 18*(4), 446-458. https://doi.org/10.1016/j.lindif.2007.11.006

Campitelli, G., & Gobet, F. (2011). Deliberate practice: Necessary but not sufficient. *Current Directions in Psychological Science, 20*(5), 280-285. https://doi.org/10.1177/0963721411421922

Campitelli, G., Gobet, F., & Bilalic, M. (2014). Cognitive processes and development of chess genius: An integrative approach. In D. K. Simonton (Ed.), *The Wiley handbook of genius* (pp. 350-374). Wiley.

Carow, J., & Witzig, N. M. (2024). *Time pressure and strategic risk-taking in professional chess (Discussion paper number 2404)*. Gutenberg School of Management and Economics, Johannes Gutenberg-Universität Mainz. https://download.uni-mainz.de/RePEc/pdf/Discussion_Paper_2404.pdf

Carrió Urra, J. (2015). Cognitive tests battery to evaluate the executive functions to chess players. *Lecturas: Educación Física y Deportes,* 204. https://www.efdeportes.com/efd204/evaluate-the-executive-functions-to-chess-players.htm

Cauzinille-Marmeche, E., & Didierjean, A. (1998). Reasoning by analogy and memory for cases in the game of chess. In K. Holyoak, D. Gentner, & B. Kokinov (Eds.), *Advances in analogy research: Integration of theory and data from the cognitive, computational, and neural sciences* (pp. 231-236). New Bulgarian University.

Celone, J. (2001). *The effects of a chess program on abstract reasoning and problem-solving in elementary school children* [Masters dissertation, Southern Connecticut State University]. https://libsearch.southernct.edu/permalink/01CSCU_SCSU/198mi7/alma991003446949703455

Chacoma, A., & Billoni, O. V. (2025). Emergent complexity in the decision-making process of chess players. *Scientific Reports, 15*(1), 23234. https://doi.org/10.1038/s41598-025-06335-9

Chang, Y.-H. A., & Lane, D. M. (2016). There is time for calculation in speed chess, and calculation accuracy increases with expertise. *The American Journal of Psychology, 129*(1), 1-9. https://doi.org/10.5406/amerjpsyc.129.1.0001

Chang, Y.-H. A., & Lane, D. M. (2018). It takes more than practice and experience to become a chess master: Evidence from a child prodigy and adult chess players. *Journal of Expertise, 1*(1), 6-34. https://www.journalofexpertise.org/articles/volume1_issue1/JoE_2018_1_1_Chang_Lane.pdf

Charchyan, A., & Karapetyan, L. (2022). Overview and analysis of the inclusive working group activity at the Chess Research Institute: (Case from Armenian

State Pedagogical University [2015-2021]). *Armenian Journal of Special Education, 5*(1), 6-16. https://doi.org/10.24234/se.v5i1.282

Charness, N., Tuffiash, M., & Jastrzembski, T. (2004). Motivation, emotion, and expert skill acquisition. In D. Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 299-320). Lawrence Erlbaum Associates.

Charness, N., Tuffiash, M., Krampe, R., Reingold, E., & Vasyukova, E. (2005). The role of deliberate practice in chess expertise. *Applied Cognitive Psychology, 19*(2), 151-165. https://doi.org/10.1002/acp.1106

Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In *Visual information processing; Proceedings of the eighth annual Carnegie symposium on cognition, held at the Carnegie-Mellon University, Pittsburgh, Pennsylvania, May 19, 1972* (pp. 215-281). https://doi.org/10.1016/B978-0-12-170150-5.50011-1

Chassy, P. (2023). Gender differences: The chess delusion. *Journal of Expertise, 6*(1), 68-80. https://www.journalofexpertise.org/articles/volume6_issue1/JoE_6_1_Chassy.pdf

Cheragh-Birjandi, S., Yazdizadeh, M., & Asghari, S. (2024). The effect of chess learning and omega-3 supplementation on serum levels of NT-3 and TrkC receptor in elderly women. *Journal of Applied Health Studies in Sport Physiology, 12*(1), 40-51. https://doi.org/10.22049/jahssp.2024.29629.1646

Chi, M. T. H. (1978). Knowledge structures and memory development. In R. S. Siegler (Ed.), *Children's thinking* (pp. 73-96). Psychology Press.

Chitiyo, G., Zagumny, L., Davis, K., Littrell, M., Akenson, A., Besnoy, K., Potter, K. (2021). Teacher perceptions of using chess as a heuristic pedagogical method: Teacher perceptions of using chess. *International Journal of Curriculum and Instruction, 13*(3), 2482-2496. https://www.ijci.net/index.php/IJCI/article/view/715/370

Chitiyo, G., Zagumny, L., Littrell, M. N., Besnoy, K., Akenson, A. B., Davis, K. M., . . . Lastres, M. (2023). Students' perceptions of the benefits of scholastic chess instruction. *Brock Education Journal, 31*(1). https://doi.org/10.26522/brocked.v31i1.890

Chole, V., Gadicha, V., & Thawakar, M. (2024). Evolution of artificial intelligence through game playing in chess: History, tools, and techniques. In *Data-driven systems and intelligent applications* (pp. 119-136). CRC Press.

Cleveland, A. A. (1907). The psychology of chess and of learning to play it. *The American Journal of Psychology, 18*(3), 269-308. https://doi.org/10.2307/1412592

Cohen, S. M., Witsell, D. L., Scearce, L., Vess, G., & Banka, C. (2008). Treatment responsiveness of the singing voice handicap index. *The Laryngoscope, 118*(9), 1705-1708. https://doi.org/10.1097/MLG.0b013e31817aec83

Costantino, A. I., Gunay, E. M., Van Hove, E., Van Hove, L., Vieira, F. F., Bilalic, M., & de Beeck, H. O. (2025). The effects of learning on the representational geometry of skilled chess players. Journal of Vision, 25(9), Article 1968. https://doi.org/10.1167/jov.25.9.1968

Creswell, J. W. (2009). *Research design: Qualitative and mixed methods approaches.* Sage Publications.

Creswell, J. W. (2021). *A concise introduction to mixed methods research*. SAGE Publications.

Cross, D. R., & Paris, S. G. (1988). Developmental and instructional analyses of children's metacognition and reading comprehension. *Journal of Educational Psychology, 80*(2), 131-142. https://doi.org/10.1037/0022-0663.80.2.131

Cullen, M. J., Hardison, C. M., & Sackett, P. R. (2004). Using SAT-grade and ability-job performance relationships to test predictions derived from stereotype threat theory. *Journal of Applied Psychology, 89*(2), 220-230. https://doi.org/10.1037/0021-9010.89.2.220

Dall'Osso Teigset, M. (2023). *Association between playing chess and solving mathematical tasks* [Masters dissertation, University of Agder, Norway].https://uia.brage.unit.no/uia-xmlui/handle/11250/3076225

Dania, A., Kaltsonoudi, K., Ktistakis, I., Trampa, K., Boti, N., & Pesce, C. (2023). Chess training for improving executive functions and invasion game tactical behavior of college student athletes: A preliminary investigation. *Physical Education and Sport Pedagogy, 28*(4), 380-396. https://doi.org/10.1080/17408989.2021.1990245

Dapica-Tejada, R. (2016). *Influencia del ajedrez en la comprensión lectora y los movimientos sacádicos en niños* [Masters dissertation, Universdidad Internacional de la Rioja, Spain]. https://reunir.unir.net/handle/123456789/4371

de Bruin, A. B., Rikers, R. M., & Schmidt, H. G. (2007a). The effect of self-explanation and prediction on the development of principled understanding of chess in novices. *Contemporary Educational Psychology, 32*(2), 188-205. https://doi.org/10.1016/j.cedpsych.2006.01.001

de Bruin, A. B., Rikers, R. M., & Schmidt, H. G. (2007b). The influence of achievement motivation and chess-specific motivation on deliberate practice. *Journal of Sport and Exercise Psychology, 29*(5), 561-583. https://doi.org/10.1123/jsep.29.5.561

de Freitas Ferreira, J. H. (2023). Chess game as an educational aid in the pedagogical process, for learning and motivation. *Uniknow Development Journal.* https://doi.org/10.56238/uniknowindevolp-114

de Groot, A. D. (1946). *Het denken van den Schaker, een experimenteel-psychologische studie.* Noord-Hollandsche Uitgevers Maatschappij.

de Groot, A. D. (1977). Memorandum: Chess instruction in the school? A few arguments and counterarguments. In H. Lyman (Ed.), *Chess in the classroom.*

An answer to NIE (pp. 1-10). The Massachusetts Chess Association and the American Chess Foundation.

de Groot, A. D. (1978). *Thought and choice in chess.* De Gruyter Mouton.de Groot, A. D. (1986). Intuition in chess. *ICCA Journal, 9*(2), 67-75. https://doi.org/10.3233/ICG-1986-9202de Groot, A. D., Gobet, F., & Jongman, R. W. (1996). *Perception and memory in chess: Studies in the heuristics of the professional eye.* Van Gorcum & Co.

de Lemios, R., Labitag, A., Loresto, S., Laguidao, A., & Santillan, J. P. (2024). Fillquation: A game-based learning material in numeracy education. *EDUCATUM Journal of Science, Mathematics and Technology, 12*(1), 107-117. https://doi.org/10.37134/ejsmt.vol12.1.11.2025

Dilmaghani, M., & Smerdon, D. (2024). *Gender differences in corrupt behaviour: Evidence from elite chess tournaments.* https://ssrn.com/abstract=4860333 or http://dx.doi.org/10.2139/ssrn.4860333

Dovom, M. M., Fatolahi, H., Nikbin, S., Noktehdan, S. F., Mohabbati, P., Bagheri, P., & Azarbayjani, M. A. (2024). Effects of official chess competition on salivary cortisol and mood swings in adolescent girls: A win–loss approach. *Applied Psychophysiology and Biofeedback, 49*, 301-311. https://doi.org/10.1007/s10484-023-09616-z

Dreyfus, H. L., & Dreyfus, S. E. (1986). From Socrates to expert systems: The limits of calculative rationality. In C. Mitcham & A. Huning (Eds.), *Philosophy and technology II: Boston studies in the philosophy of science* (vol. 90, pp. 111-130):.Springer Netherlands.

Eales, R. G. (1985). *Chess: The history of a game.* BT Batsford Limited.

Eberhard, J. W. (2003). *The relationship between classroom chess instruction and verbal, quantitative, and nonverbal reasoning abilities of economically disadvantaged students* [Doctoral dissertation, Texas A&M University-Kingsville].

Eisma, K., & Winter, D. (2024). Turing tests in chess: An experiment revealing the role of human subjectivity. *Computers in Human Behavior Reports*, *16*, 100496. https://doi.org/10.1016/j.chbr.2024.100496

Ekizoğlu, Ö., Yazici, N. A., Isik, U., Acet, M., & Gümüsgül, O. (2023). The rehabilitative effect of chess on the visually impaired. *Loisir et Société/Society and Leisure, 46*(2), 354-366. https://doi.org/10.1080/07053436.2023.2216592

ElDaou, B. M. N., & El-Shamieh, S. I. (2015). The effect of playing chess on the concentration of ADHD students in the 2nd cycle. *Procedia-Social and Behavioral Sciences, 192*, 638-643. https://doi.org/10.1016/j.sbspro.2015.06.111

Elo, A. E. (1978). *The rating of chess players, past and present*. Arco Publishing.

Erhan, E., Hazar, M., & Tekin, M. (2010). Satranç oynayan ve oynamayan ilköğretim oğrencilerinin problem cözme becerilerinin incelenmesi [Investigating the problem solving skills of primary school students who are playing chess or not]. *Beden Eğitimi ve Spor Bilimleri Dergisi, 11*(2). https://dergipark.org.tr/en/download/article-file/297041

Ericsson, K. A. (2018). The differential influence of experience, practice, and deliberate practice on the development of superior individual performance of experts. In K. A. Ericsson, R. R. Hoffman, A. Kozbelt, & A. M. Williams (Eds.), *The Cambridge handbook of expertise and expert performance* (2nd ed.) (pp. 745-769). Cambridge University Press.

Ericsson, K. A. (2019). Towards a science of the acquisition of expert performance in sports: Clarifying the differences between deliberate practice and other types of practice. *Journal of Sports Sciences, 38*(2), 159-176. https://doi.org/10.1080/02640414.2019.1688618

Ericsson, K. A., & Harwell, K. W. (2019). Deliberate practice and proposed limits on the effects of practice on the acquisition of expert performance: Why the original definition matters and recommendations for future research. *Frontiers in Psychology, 10*, 2396. https://doi.org/10.3389/fpsyg.2019.02396

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363-406. https://doi.org/10.1037/0033-295X.100.3.363

Esau, O. (2023). Reducing violence through chess: Involving pre-service teachers in participatory action in schools. *The Canadian Journal of Action Research, 23*(3), 97-111. https://doi.org/10.33524/cjar.v23i3.617

Expósito Barrios, P. (2017). *La transferencia del ajedrez en las capacidades cognitivas y las habilidades sociopersonales de alumnos de primaria: Revisión teórica [A theoretical review of the transfer from chess instruction to cognitive, social and personal skills in primary students]* [Bachelor's dissertation, Universidad de La Laguna]. http://riull.ull.es/xmlui/handle/915/5623

Eysenck, H., & Wilson, G. (2000). Kak izmenit "lichnost" [How to change a personality] (A. Belopolski, Trans.). OOO Kogito-Tsentr.

Ezennaka, A. O., & Unachukwu, G. (2023a). Effects of chess playing on the reflective thinking skill of the adolescent students in Anambra State secondary schools. *UNIZIK Journal of Educational Research and Policy Studies, 16*(1), 133-145. https://www.unijerps.org/index.php/unijerps/article/view/474

Ezennaka, A. O., & Unachukwu, G. (2023b). Chess playing and gender effect on attention skill of the adolescent students in Anambra State of Nigeria. *African Journal of Educational Management, Teaching and Entrepreneurship Studies, 9*(2), 1-15. https://www.ajemates.org/index.php/ajemates/article/view/267

Ferguson, R. (1986). *Developing critical and creative thinking through chess.* Paper presented at the annual conference of the Pennsylvania Association for Gifted Education, Pittsburgh, Pennsylvania. https://www.geocities.ws/chess_camp/research_summary.

Fernández Amigo, J. (2008). *Use of teaching materials with chess resources for the teaching of mathematics. Study of its effects on a sample of 2nd grade students* [Doctoral dissertation, Universitat Autònoma de Barcelona]. https://www.tdx.cat/handle/10803/5053#page=1

Ferrari, V., Didierjean, A., & Marmeche, E. (2006). Dynamic perception in chess. *Quarterly Journal of Experimental Psychology, 59*(2), 397-410. https://doi.org/10.1080/17470210500151428

Ferrari, V., Didierjean, A., & Marmeche, E. (2008). Effect of expertise acquisition on strategic perception: The example of chess. *Quarterly Journal of Experimental Psychology, 61*(8), 1265-1280. https://doi.org/10.1080/17470210701503344

Ferreira, D., & Palhares, P. (2008). Chess and problem solving involving patterns. *The Mathematics Enthusiast, 5*(2), 249-256. https://doi.org/10.54870/1551-3440.1105

Fine, R. (1965). The psychology of blindfold chess. *Acta Psychologica, 24*(4), 352-370. https://doi.org/10.1016/0001-6918(65)90021-1

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Flavell, J. H., & Wellman, H. (1977). *Metamemory.* Paper presented at the annual meeting of the American Psychological Association, Chicago, IL. https://files.eric.ed.gov/fulltext/ED115405.pdf

Frederiksen, N. (1984). Implications of cognitive theory for instruction in problem solving. *Review of Educational Research, 54*(3), 363-407. https://doi.org/10.3102/00346543054003363

Freeman, R. E., & Reed, D. L. (1983). Stockholders and stakeholders: A new perspective on corporate governance. *California Management Review, 25*(3), 88-106. https://doi.org/10.2307/41165018

Fried, S., & Ginsburg, N. (1987). *The effect of learning to play chess on cognitive, perceptual and emotional development in children* [Unpublished manuscript]. US Chess Federation.

Frydman, M., & Lynn, R. (1992). The general intelligence and spatial abilities of gifted young Belgian chess players. *British Journal of Psychology, 83*(2), 233-235. https://doi.org/10.1111/j.2044-8295.1992.tb02437.x

Fuentes-García, J. P., Martínez Patiño, M. J., Villafaina, S., & Clemente-Suárez, V. J. (2020). The effect of COVID-19 confinement in behavioral, psychological, and training patterns of chess players. *Frontiers in Psychology, 11*, 1812. https://doi.org/10.3389/fpsyg.2020.01812

Fuentes-García, J. P., & Villafaina, S. (2024). Psychophysiological and performance effects of biofeedback and neurofeedback interventions in a top 100 female chess player. *Behavioral Sciences, 14*(11), 1044. https://doi.org/10.3390/bs14111044

Fuhl, W., & Hyseni, G. (2024). *Gaze-based assessment of expertise in chess.* In *Proceedings of the 2024 symposium on eye tracking research and applications (ETRA '24)* (article 42). Association for Computing Machinery.

Galitis, I. (2002). Stalemate: Girls and a mixed-gender chess club. *Gender and Education, 14*(1), 71-83. https://doi.org/10.1080/09540250120098898

Gardiner, G. C. (2018). *Learning chess and the development of cognitive thinking in Queensland primary schools: An exploratory study* [Masters dissertation, University of Southern Queensland, Australia]. https://doi.org/10.26192/5f7bff4cec17d

Gardiner, G., van der Laan, L., & Ormsby, G. (2019). Most people think playing chess makes you ‘smarter’, but the evidence isn’t clear on that. *The Conversation, 11*, 1-7. https://theconversation.com/most-people-think-playing-chess-makes-you-smarter-but-the-evidence-isnt-clear-on-that-119469

Gates, R. L. (2015). *Chess instruction in the mathematics classroom: Implications for critical-thinking and academic skills: A meta-synthesis* [Masters dissertation, University of Alaska Southeast].https://scholarworks.alaska.edu/handle/11122/12580

Gaudreau, L. (1992). *A study comparing the challenging mathematics curriculum to traditional math.* La Chenelië re & McGraw Hill.

Gauvain, M., & Rogoff, B. (1989). Collaborative problem solving and children’s planning skills. *Developmental Psychology, 25*(1), 139-151. https://doi.org/10.1037/0012-1649.25.1.139

Gerdes, C., & Gränsmark, P. (2010). Strategic behavior across gender: A comparison of female and male expert chess players. *Labour Economics, 17*(5), 766-775. https://doi.org/10.1016/j.labeco.2010.04.013

Gevorkyan, S. R., Manukyan, S. A., & Sarkisyan, V. Z. (2023). The impact of students’ attitudes and learning activities on the chess academic achievements in primary schools. *Ïñèõîëîãè× Åñêàß Íàóêà È Îáðàçîâàíèå Psychological Science and Education, 28*(5), 101. https://psyjournals.ru/journals/pse/archive/pse_2023_n5.pdf

Giouvantsioudis, K. (2024). Chess as an educational tool. *Main Issues of Pedagogy and Psychology, 11*(2), 148-171. https://doi.org/10.24234/miopap.v11i2.37

Gliga, F., & Flesner, P. I. (2014). Cognitive benefits of chess training in novice children. *Procedia-Social and Behavioral Sciences, 116*, 962-967. https://doi.org/10.1016/j.sbspro.2014.01.328

Glukhova, O. V., Volikova, S. V., Zaretskii, Y. V., & Zaretskii, V. K. (2022). The results of a longitudinal diagnostic study on the project “Chess for overall development”. *Konsul’tativnaya psikhologiya psikhoterapiya /Counseling, Psychology and Psychotherapy, 30*(1), 49-75. https://doi.org/10.17759/cpp.2022300404

Glukhova, O. V. (2017). The need for chess in school and its role in the dynamics of child development. *Revue Internationale du CRIRES: Innover dans la tradition de Vygotsky, 4*(1), 161-168. https://doi.org/10.51657/ric.v4i1.41000

Gobet, F. (1998). Chess players’ thinking revisited. *Swiss Journal of Psychology/ Schweizerische Zeitschrift für Psychologie / Revue Suisse de Psychologie, 57*(1), 18-32. http://bura.brunel.ac.uk/handle/2438/822

Gobet, F. (2017). Three views on expertise: Philosophical implications for rationality, knowledge, intuition and education. *Journal of Philosophy of Education, 51*(3), 605-619. https://doi.org/10.1111/1467-9752.12253

Gobet, F. (2018). The future of expertise: The need for a multidisciplinary approach. *Journal of Expertise, 1*(2), 107-113. https://journalofexpertise.org/articles/volume1_issue2/JoE_2018_1_2_Gobet.pdf

Gobet, F. (2018). *The psychology of chess*. Routledge.

Gobet, F., & Campitelli, G. (2006). *Educational benefits of chess instruction: A critical review.* In T. Redman (Ed.), *Chess and education: Selected essays from the Koltanowski conference* (pp. 124-143). University of Texas Chess Program.

Gobet, F., & Chassy, P. (2009). Expertise and intuition: A tale of three theories. *Minds & Machines, 19*, 151-180. https://doi.org/10.1007/s11023-008-9131-5

Gobet, F., & Jansen, P. J. (2006). Training in chess: A scientific approach. In T. Redman (Ed.), *Education and chess*. http://www.chrest.info/fg/preprints/Training_in_chess.PDF

Gobet, F., & Lane, P. C. R. (2010). The CHREST architecture of cognition: The role of perception in general intelligence. In *Proceedings of the 3rd conference on artificial general intelligence: AGI-2010 Atlantis Press.* https://doi.org/10.2991/agi.2010.20

Gobet, F., Lane, P. C. R., Croker, S., Cheng, P. C., Jones, G., Oliver, I., & Pine, J. M. (2001). Chunking mechanisms in human learning. *Trends in Cognitive Sciences, 5*(6), 236-243. https://doi.org/10.1016/S1364-6613(00)01662-4

Gobet, F., & Simon, H. A. (1996a). The roles of recognition processes and look-ahead search in time-constrained expert problem solving: Evidence from grand-master-level chess. *Psychological Science, 7*(1), 52-55. https://doi.org/10.1111/j.1467-9280.1996.tb00666.x

Gobet, F., & Simon, H. A. (1996b). Recall of rapidly presented random chess positions is a function of skill. *Psychonomic Bulletin & Review, 3*(2), 159-163. https://doi.org/10.3758/BF03212414

Gobet, F., & Simon, H. A. (1996c). Recall of random and distorted chess positions: Implications for the theory of expertise. *Memory & Cognition, 24*(4), 493-503. https://doi.org/10.3758/BF03200937

Gobet, F., & Simon, H. A. (1998). Expert chess memory: Revisiting the chunking hypothesis. *Memory, 6*(3), 225-255. https://doi.org/10.1080/741942359

Gobet, F., & Simon, H. A. (2000). Five seconds or sixty? Presentation time in expert memory. *Cognitive Science, 24*(4), 651-682. https://doi.org/10.1207/s15516709cog2404_4

Gong, Y., Ericsson, K. A., & Moxley, J. H. (2015). Recall of briefly presented chess positions and its relation to chess skill. *PloS One, 10*(3), 1-20. https://doi.org/10.1371/journal.pone.0118756

Gonzalez-Burgos, L., Lozano-Rodriguez, C., Molina, Y., Garcia-Cabello, E., Aciego, R., Barroso, J., & Ferreira, D. (2024). The effect of chess on cognition: A graph theory study on cognitive data. *Frontiers in Psychology, 15*, 1407583. https://doi.org/10.3389/fpsyg.2024.1407583

González-Díaz, J., Palacios-Huerta, I., & Abuín, J. M. (2024). Personal bests and gender. *Review of Economics and Statistics, 106*(2), 409-422. https://doi.org/10.1162/rest_a_01145

Grabner, R. H. (2014). The role of intelligence for performance in the prototypical expertise domain of chess. *Intelligence, 45*, 26-33. https://doi.org/10.1016/j.intell.2013.07.023

Grau-Pérez, G., & Moreira, K. (2017). A study of the influence of chess on the Executive Functions in school-aged children [Estudio del impacto del ajedrez sobre las Funciones Ejecutivas en niños de edad escolar]. *Studies in Psychology, 38*(2), 473-494. https://doi.org/10.1080/02109395.2017.1295578

Green, A. E., & Aarons, G. A. (2011). A comparison of policy and direct practice stakeholder perceptions of factors affecting evidence-based practice implementation using concept mapping. *Implementation Science, 6*(1), 1-12. http://dx.doi.org/10.1186/1748-5908-6-104

Gundawar, A., Li, Y., & Bertsekas, D. (2024). Superior computer chess with model predictive control, reinforcement learning, and rollout. *arXiv preprint arXiv:2409.06477*. https://doi.org/10.48550/arXiv.2409.06477

Gunes, G., & Tugrul, B. (2016). Is chess just a game, or is it a mirror that reflects or is it a mirror that reflects the child's inner world*? International Journal of Research in Education and Science (IJRES), 3*(2), 438-451. https://doi.org/10.21890/ijres.327902

Guskey, T. R. (2007). Using assessments to improve teaching and learning. In D. Reeves (Ed.), *Ahead of the curve: The power of assessment to transform teaching and learning* (pp. 15-29). Solution Tree.

Hainey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education, 102*, 202-223. https://doi.org/10.1016/j.compedu.2016.09.001

Hair, J., Black, W., Babin, B., & Anderson, R. (2019). Multivariate data analysis. Cengage Learning.

Hambrick, D. Z., Oswald, F. L., Altmann, E. M., Meinz, E. J., Gobet, F., & Campitelli, G. (2014). Deliberate practice: Is that all it takes to become an expert? *Intelligence, 45*, 34-45. https://doi.org/10.1016/j.intell.2013.04.001

Hammond, M. S. (2014). *The utilization of chess to enhance children's academic performance: An integrative review* [Masters dissertation, University of Northern British Columbia]. https://core.ac.uk/download/pdf/84875169.pdf

Hartman, H. J. (1998). Metacognition in teaching and learning: An introduction. *Instructional Science, 26*(1), 1-3. https://doi.org/10.1023/A:1003023628307

Heck, P. R., Benjamin, D. J., Simons, D. J., & Chabris, C. F. (2024). Overconfidence persists despite years of accurate, precise, public, and continuous feedback: Two studies of tournament chess players. https://doi.org/10.31234/osf.io/yd5he_v2

Helsen, W. F., Baker, J., Schorer, J., Steingroever, C., Wattie, N., & Starkes, J. L. (2016). Relative age effects in a cognitive task: A case study of youth chess. *High Ability Studies, 27*(2), 211-221. https://doi.org/10.1080/13598139.2016.1242063

Hermelin, R. (2010). *The effect of playing chess on the mathematics achievement of primary school learners in two schools in KZN* [Masters dissertation, University of KwaZulu-Natal]. https://researchspace.ukzn.ac.za/items/02c22542-2430-4c16-b6eb-5df58b48b6bb

Hichem, B., Taleb, A., Hadj, B., & Said, B. (2023). The effect of chess on thinking patterns according to Hermann's scale. *Journal of Physical Education and Sport, 23*(4), 1056-1063. https://doi.org/10.7752/jpes.2023.04132

Hong, S., & Bart, W. M. (2007). Cognitive effects of chess instruction on students at risk for academic failure. *International Journal of Special Education, 22*(3), 89-96. https://repository.isls.org/handle/1/3635

Horgan, D. D. (1990). *Students' predictions of test grades: Calibration and metacognition.* Paper presented at the annual meeting of the American Educational Research Association, Boston, MA. https://files.eric.ed.gov/fulltext/ED319812.pdf

Horgan, D. D., & Morgan, D. (1986). *Chess and education. ERIC-Memphis State University*. https://files.eric.ed.gov/fulltext/ED275408.pdf

Horgan, D. D. (1987). Chess as a way to teach thinking. *Teaching, Thinking and Problem Solving, 9*, 4-11. https://www.uschesstrust.org/wp-content/uploads/2007/07/Chess-As-A-Way-To-Teach-Thinking-by-Dianne-D.-Horgan.pdf

Horgan, D. D. (1992). Children and chess expertise: The role of calibration. *Psychological Research, 54*(1), 44-50. https://doi.org/10.1007/BF01359223

Horgan, D. D., & Morgan, D. (1990). Chess expertise in children. *Applied Cognitive Psychology, 4*(2), 109-128. https://doi.org/10.1002/acp.2350040204

Howard, R. W. (1999). Preliminary real-world evidence that average human intelligence really is rising. *Intelligence, 27*(3), 235-250. https://doi.org/10.1016/S0160-2896(99)00018-5

i Canadell, J. B., Barceló-Soler, A., de la Torre Rivero, F., Solé, S., Demarzo, M., Garcia-Campayo, J., & Canals, C. S. (2021). *Effects of mindfulness-and acceptance-based interventions on performance and psychological variables in chess: A systematic review.* https://www.researchgate.net/profile/Marcelo-Demarzo/publication/348192285_Effects_of_mindfulness-_and_acceptance-based_interventions_on_performance_and_psychological_variables_in_chess_A_systematic_review/links/5ff3581aa6fdccdcb82e7133/Effects-of-mindfulness-and-acceptance-based-interventions-on-performance-and-

psychological-variables-in-chess-A-systematic-review.pdf
https://doi.org/10.13140/RG.2.2.27358.66883

Inayatullah, S. (1998). Causal layered analysis: Poststructuralism as method. *Futures, 30*(8), 815-829. https://doi.org/10.1016/S0016-3287(98)00086-X

Inayatullah, S. (2002). Reductionism or layered complexity? The futures of futures studies. *Futures, 34*(3-4), 295-302. https://doi.org/10.1016/S0016-3287(01)00045-3

Islam, A., Lee, W.-S., & Nicholas, A. (2021). The effects of chess instruction on academic and non-cognitive outcomes: Field experimental evidence from a developing country. *Journal of Development Economics, 150*, 102615. https://doi.org/10.1016/j.jdeveco.2020.102615

Jenifer, J. B., Jaxon, J., Levine, S. C., & Cimpian, A. (2024). “You need to be super smart to do well in math!” Young children’s field-specific ability beliefs. *Developmental Science, 27*(1), e13429. https://doi.org/10.1111/desc.13429

Jerrim, J., Macmillan, L., Micklewright, J., Sawtell, M., & Wiggins, M. (2016). *Chess in schools - evaluation report and executive summary.* Education Endowment Foundation, Institute of Education, University College London. https://files.eric.ed.gov/fulltext/ED581100.pdf

Jerrim, J., Macmillan, L., Micklewright, J., Sawtell, M., & Wiggins, M. (2018). Does teaching children how to play cognitively demanding games improve their educational attainment? Evidence from a randomized controlled trial of chess instruction in England. *Journal of Human Resources, 53*(4), 993-1021. https://doi.org/10.3368/jhr.53.4.0516.7952R

Jianguo, P., Wenying, J., Zhigang, H., & Zhou, N. (2019). The influence of chess training on pupils’ self-efficacy, self-esteem and social anxiety. In *SHS Web of conferences* (Vol. 60, p. 01002). EDP Sciences. https://doi.org/10.1051/shsconf/20196001002

Jongman, R. W. (1968*). Het oog van de meester [The eye of the master].* Van Gorcum.

Joseph, E., Chandrasekaran, S., Tr., U., & Easvaradoss, V. V. (2017). Improving perceptual reasoning in school children through chess training. In *Proceedings of the annual meeting of the Cognitive Science Society* (vol. 39). https://escholarship.org/uc/item/6qr3751h

Joseph, E., Easvaradoss, V. V., Abraham, S., & Chan, M. A. (2017). Mentoring children through chess training enhances cognitive functions. *International Journal of Information and Education Technology, 7*(9), 669-672. https://doi.org/10.18178/ijiet.2017.7.9.951

Joseph, E., Easvaradoss, V. V., Abraham, S., & Chandran, D. (2021). Thinking out of the box, enhancing creativity and divergent thinking through chess training. *Revista Mundi Engenharia, Tecnologia e Gestão, 6*(1). https://doi.org/10.21575/25254782rmetg2021vol6n11525

Joseph, E., Easvaradoss, V. V., Abraham, S., & Jain, S. (2018). Enhancing verbal reasoning of school children through chess learning. *International Journal of*

Scientific Engineering and Science, 2(7), 1-3. https://ijses.com/wp-content/uploads/2018/07/181-IJSES-V2N6.pdf

Joseph, E., Easvaradoss, V. V., Abraham, S., & Vaddadi, S. (2020). Malleability of working memory through chess in schoolchildren — a two-year intervention study. In *Proceedings of the annual meeting of the Cognitive Science Society* (vol. 42). https://escholarship.org/uc/item/55g8446v

Joseph, E., Easvaradoss, V. V., Chandran, D., Jain, S., & Paul, A. (2018). Impact of chess learning on processing speed of school-going children. *Advances in Social Sciences Research Journal, 5*(6). https://doi.org/10.14738/assrj.56.4797

Joseph, E., Easvaradoss, V. V., Kennedy, A., & Kezia, E. J. (2016). Chess training improves cognition in children. *GSTF Journal of Psychology, 2*(2). https://doi.org/10.5176/2345-7872_2.2_33

Joseph, E., Easvaradoss, V. V., & Solomon, N. J. (2016). Impact of chess training on academic performance of rural Indian school children. *Open Journal of Social Sciences, 4*(2), 20-24. https://doi.org/10.4236/jss.2016.42004

Joseph, E., Manoharan, S., Easvaradoss, V. V., & Chandran, D. (2017). A study on the impact of chess training on creativity of Indian school children. In *Proceedings of the annual meeting of the Cognitive Science Society* (vol. 39). https://escholarship.org/uc/item/11g4567d

Kalwij, A., & De Jaegher, K. (2023). The age-performance relationship for a cognitive-intensive task: Empirical evidence from chess grandmasters. *Sports Economics Review, 2*, 100010. https://doi.org/10.1016/j.serev.2023.100010

Karakuş, G. (2023). Chess and education. *Educational Considerations, 49*(2), 5. https://doi.org/10.4148/0146-9282.2365

Karapetyan, V. S. (2021a). Regular manifestations of algorithmic thinking and chess prior knowledge. *Редакционная коллегия*, 41-43. https://fpmi.elsu.ru/archive/2021/docs/abstracts.pdf

Karapetyan, V. S. (2021b). Functions of algorithmic thinking in the process of demonstrating chess skills. *Problems of Psychology in the 21st Century, 15*(2), 48-52. https://doi.org/10.33225/ppc/21.15.48

Karimi, S., & Mahmoudfakhe, H. (2024). The effect of transcranial Direct Current Stimulation (tDCS) on visual attention and response control in chess players. *Sport Psychology Studies, 13*(48), 145-158. https://doi.org/10.22089/spsyj.2024.14745.2395

Kazemi, F. (2022). The effect of chess instruction on mathematics motivational strategies for learning and error model of students' problem solving based on Newman Model. *Journal of Algebraic Statistics, 13*(2), 2698-2716. https://www.publishoa.com/index.php/journal/article/view/507/437

Kazemi, F., Yektayar, M., & Abad, A. M. B. (2012). Investigation the impact of chess play on developing meta-cognitive ability and math problem-solving power of students at different levels of education. *Procedia-Social and Behavioral Sciences, 32*, 372-379. https://doi.org/10.1016/j.sbspro.2012.01.056

Ke, F., & Moon, J. (2018). Virtual collaborative gaming as social skills training for high-functioning autistic children. *British Journal of Educational Technology, 49*(4), 728-741. https://doi.org/10.1111/bjet.12626

Khachatryan, H., Khachatryan, S., Movsisyan, N., & Gevorgyan, L. (2024). The enhancement of students' critical thinking with the use of chess. *Scientia Paedagogica Experimentalis, 61*(1), 105-120. https://doi.org/10.57028/S61-105-Z1055

Khosrorad, R., Kouhbanani, S. S., & Sanii, A. (2014). Chess training for improving executive functions and mathematics performance of students with mathematics disorders. *International Journal of Educational Investigations, 1*(1), 283-295. http://www.ijeionline.com/attachments/article/31/IJEIonline_Vol.1_No.1_pp.283-295_code32_2.pdf

Koenig, T. (2024). *Tracking the evolution of artificial intelligence through the lens of its ability to play chess* [Bachelor's dissertation, Yeshiva University]. https://repository.yu.edu/items/61be1a3b-1946-494d-bfcf-9bb06c39d933

Koerts, R. (2024). Assessing perceived humanness of artificial intelligence in chess [Masters dissertation, TU Delft]. http://resolver.tudelft.nl/uuid:267fd3ff-3ca0-42b5-97a0-ca571dcbb6be

Kramarski, B., Mevarech, Z. R., & Arami, M. (2002). The effects of metacognitive instruction on solving mathematical authentic tasks. *Educational Studies in Mathematics, 49*, 225-250. https://doi.org/10.1023/A:1016282811724

Krivec, J. (2022). Chess as a tool for developing 21st century skills with a deliberate practice approach. *Informacijska Družba–Is 2022*, 27. https://is.ijs.si/wp-content/uploads/2022/10/IS2022_Volume-D-TEMP.pdf

Küchelmann, T., Velentzas, K., Essig, K., & Schack, T. (2024). Expertise-dependent visuocognitive performance of chess players in mating tasks: Evidence from eye movements during task processing. *Frontiers in Psychology, 15*, 1294424. https://doi.org/10.3389/fpsyg.2024.1294424

Kuhn, D. (2000). Metacognitive development. *Current Directions in Psychological Science, 9*(5), 178-181. https://doi.org/10.1111/1467-8721.00088

Lammers, F. (2016). *"Because it trains my mind": Assessing the cognitive and scholastic effects of chess instruction in primary schools of the Soweto Township* [Masters dissertation, Institute of Development Research and Development Policy, Ruhr-University Bochum. https://wusgermany.de/sites/default/files/content/files/lammers.pdf

Lastima, D. G., & Gayoles, L. A. M. (2020). Effects of chess training on the psychological well-being of children in conflict with the law. *Philippine Social Science Journal, 3*(2), 137-138. https://doi.org/10.52006/main.v3i2.141

Laws, B. C. (2014). The phenomenon of abstract cognition among scholastic chess participants: A case study [Doctoral dissertation, East Tennessee State University]. https://dc.etsu.edu/etd/2458

Leong, C., Lin, Y., Zhang, J., & Yuan, Z. (2024). How time pressure modulates individual differences in the functional connectivity of chunk memory in chess games. *Neuroscience, 552*, 39-46. https://doi.org/10.1016/j.neuroscience.2024.05.026

Leong, C., Zhao, Z., Yuan, Z., & Liu, B. (2024). Distinct brain network organizations between club players and novices under different difficulty levels. *Brain and Behavior, 14*(4), e3488. https://doi.org/10.1002/brb3.3488

Lillo-Crespo, M., Forner-Ruiz, M., Riquelme-Galindo, J., Ruiz-Fernández, D., & García-Sanjuan, S. (2019). Chess practice as a protective factor in dementia. *International Journal of Environmental Research and Public Health, 16*(12), 2116. https://doi.org/10.3390/ijerph16122116

Lin, X., & Lehman, J. D. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 36*(7), 837-858. https://doi.org/10.1002/(SICI)1098-2736(199909)36:7%3C837::AID-TEA6%3E3.0.CO;2-U

Linhares, A. (2005). An active symbols theory of chess intuition. *Minds and Machines, 15*(2), 131-181. https://link.springer.com/article/10.1007/s11023-005-5045-7

Linhares, A., & Freitas, A. E. T. (2010). Questioning Chase and Simon's (1973) “perception in chess”: The “experience recognition” hypothesis. *New Ideas in Psychology, 28*(1), 64-78. https://doi.org/10.1016/j.newideapsych.2009.07.008

Louedec, J. L., Guntz, T., Crowley, J. L., & Vaufreydaz, D. (2019). Deep learning investigation for chess player attention prediction using eye-tracking and game data. In *Proceedings of the 11th ACM Symposium on Eye Tracking Research & Applications (ETRA '19)* (Article 1, 1-9). Association for Computing Machinery. https://doi.org/10.1145/3314111.3319827

Lutfilloevna, B. G., & Kumar, V. R. (2024). Influence of chess games on children’s Health. *Ethiopian International Journal of Multidisciplinary Research, 11*(05), 132-135. https://www.eijmr.org/index.php/eijmr/article/view/1476

Mahmudov, A. K., Rakhimov, B. K., Toshmatova, M. D., & Khalilova, R. A. (2020). Didactic potential of chess game and its influence on student achievement. *PalArch's Journal of Archaeology of Egypt/Egyptology, 17*(6), 11088-11098. https://archives.palarch.nl/index.php/jae/article/view/2804

Makhova, A. (2017). Chess game as a factor in improving the quality of life of students with disabilities. *Contemporary Problems of Social Work, 24*(2017), 84-91. https://doi.org/10.17922/2412-5466-2017-3-1-84-91

Malvasi, V., Gil-Quintana, J., & Bocciolesi, E. (2022). The projection of gamification and serious games in the learning of mathematics multi-case study of secondary schools in Italy. *Mathematics, 10*(3), 336. https://www.mdpi.com/2227-7390/10/3/336

Mamani Celiz, E., & Seleme Gandolfo, A. M. (2020). *La enseñanza del ajedrez para la comprensión lectora en estudiantes de primaria de la Unidad Educativa*

“Kalajawira” de la ciudad de La Paz, gestión 2019 [The teaching of chess for reading comprehension in primary students of the “Kalajawira” educational unit of the city of La Paz, 2019 management]. https://repositorio.umsa.bo/bitstream/handle/123456789/24961/T-1361.pdf

Mărăcine, E.-M., & Mihăilescu, N.-L. (2023). Study on the choice of the optional subject “Chess Education” in the school year 2021-2022. *Logos Universality Mentality Education Novelty: Social Sciences, 12*(2), 28-38. https://doi.org/10.18662/lumenss/12.2/89

Mărăcine, E.-M., & Mihăilescu, N.-L. (2024). Study of the impact of chess practice on the development of psychosocial behavior of fifth grade school children (11-12 years). *Health, Sports & Rehabilitation Medicine, 25*(1), 9-16. https://doi.org/10.26659/pm3.2024.25.1.9

Maroju, R., Jamanzi, H., Viqer, M., & Dattel, A. R. (2024). Can proficiency in chess predict situation awareness in a novel task? *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 68*(1), 621-623. https://doi.org/10.1177/107118132412775

Martinez, E. E. (2012). *The impact of scholastic instrumental music and scholastic chess study on the standardized test scores of students in Grades Three, Four, and Five* [Doctoral dissertation, Five Towns College]. https://f94006.eos-intl.net/F94006/OPAC/Search/SimpleSearch.aspx

Martínez Ramírez, J. A. (2021). *The effects of gender-segregated competition on learning and performance in chess* [Masters dissertation, Universidad de Bogota]. http://hdl.handle.net/20.500.12010/22156

Masharipova, M., & Matyusupov, Q. (2023). Development of memory and logical thinking of children of primary school age in the process of learning the game of chess. *Science and Innovation, 2*(B3), 313-319.

Mashuri, H. (2015). Pengaruh latihan permainan catur terhadap prestasi akademik siswa SD Se-Kabupaten Trenggalek. *Jurnal Sportif: Jurnal Penelitian Pembelajaran, 1*(1), 1-8. https://doi.org/10.29407/js_unpgri.v1i1.570

McGregor, D. (2007). *Developing thinking; developing learning: A guide to thinking skills in education*. Open University Press.

Mechner, F. (2010). Chess as a behavioral model for cognitive skill research [Review of *Blindfold chess* by Eliot Hearst and John Knott]. *Journal of the Experimental Analysis of Behavior, 94*(3), 373-376. https://doi.org/10.1901/jeab.2010.94-373

Mechner, F., Fredrick, T., & Jenkins, T. (2013). How can one specify and teach thinking skills? *European Journal of Behavior Analysis, 14*(2), 285-293. https://doi.org/10.1080/15021149.2013.11434461

Medvegy, Z., Mihalovits, M., Medvegy, M., Zabos, I., & Sterbenz, T. (2022). Does playing chess strengthen resilience? *Studia Universitatis Babes-Bolyai, Educatio Artis Gymnasticae, 67*(3), 5-18. https://doi.org/10.24193/subbeag.67(3).19

Meece, J. L., Blumenfeld, P. C., & Hoyle, R. H. (1988). Students' goal orientations and cognitive engagement in classroom activities. *Journal of Educational Psychology, 80*(4), 514-523. https://doi.org/10.1037/0022-0663.80.4.514

Melkonyan, N., Tanajyan, K., & Khachatryan, H. (2024). Prospects and features of implementation of project-based learning in the context of "Chess" as a school subject in primary school. *Main Issues of Pedagogy and Psychology, 11*(2), 106-118. https:doi.org/10.24234/miopap.v11i2.57

Meloni, C., & Fanari, R. (2019). *Chess training effect on meta-cognitive processes and academic performance*. Paper presented at the 16th International Conference on Cognition and Exploratory Learning in the Digital Age (CELDA 2019). https://doi.org/10.33965/celda2019_201911L048

Meloni, C., & Fanari, R. (2021). Does chess training affect meta-cognitive processes and academic performance? In D. Ifenthaler, D. G. Sampson, & P. Isaías (Eds.), *Balancing the tension between digital technologies and learning sciences: Cognition and exploratory learning in the digital age* (pp. 19-32). Springer.

Mijaică, R., & Rendi, E. (2020). The chess-means of developing attention, memory and understanding text to children of 6-7 years old from preparatory class. *Bulletin of the Transilvania University of Brasov. Series IX, Sciences of Human Kinetics, 13*(2), 201-210. https://doi.org/10.31926/but.shk.2020.13.62.2.26

Miłosz, S., & Kapusta, P. (2024). Predicting chess puzzle difficulty with transformers. In *2024 IEEE International Conference on Big Data* (pp. 8377-8384). IEEE.

Mirzakhanyan, R., Gevorgyan, S., Sargsyan, V., & Daveyan, H. (2017). Analysis of the efficiency of teaching chess in schools. *Sociology Study, 7*(1), 36-42. https://doi.org/:10.17265/2159-5526/2017.01.006

Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2011). Metacognitive scaffolding in an innovative learning arrangement. *Instructional Science, 39*(6), 785-803. https://doi.org/10.1007/s11251-010-9154-1

Monroe, D., & Chalmers, P. A. (2024). Mastering chess with a transformer model. *arXiv preprint arXiv:2409.12272*. https://doi.org/10.48550/arXiv.2409.12272

Montero, B., & Evans, C. D. A. (2011). Intuitions without concepts lose the game: Mindedness in the art of chess. *Phenomenology and the Cognitive Sciences, 10*(2), 175-194. https://doi.org/10.1007/s11097-010-9192-9

More, A., Ramishte, O. L., Shaikh, S. K., Shinde, S., & Mali, Y. K. (2024). *Chain-checkmate: Chess game using blockchain.* Paper presented at the 15th International Conference on Computing Communication and Networking Technologies (ICCCNT), Kamand, India. https://doi.org/10.1109/ICCCNT61001.2024.10725572

Mukhamedjanova, F. R. (2020). Influence of mental load on neurovegetative regulation of heart rhythm in young chess players. *European Journal of Molecular & Clinical Medicine, 7*(2), 2314-2319. https://doi.org/10.5281/zenodo.10326226

Mukhamejhanova, F. R., & Sadikov, A. (2024). Features of neurofunctional manifestations of mental tension in children chess players. *Science and Innovation, 3*(D4), 415-419. https://doi.org/10.5281/zenodo.11098324

Nechio, D. E. (2016). *Chess practice and executive functioning in a post-secondary student diagnosed with ADHD: A single case study* [Masters dissertation, University of Saskatchewan]. https://harvest.usask.ca/items/8597b16e-2956-4a2f-b0dc-5a009e9636d1Neuman, W. L. (2006). *Social research methods: Qualitative and quantitative approaches* (6th ed.). Pearson.

Nicotera, A., & Stuit, D. (2014). *Literature review of chess studies.* Chess Club and Scholastic Center of Saint Louis. https://rknights.org/wp-content/uploads/Literature-Review-of-Chess-Studies-November-2014.pdf

Noir, M. (2002). *Le développement des habiletés cognitives de l'enfant par la pratique du jeu d'échecs: Essai de modélisation d'une didactique du transfert [The development of the child's cognitive skills through the practice of chess: an attempt to model transfer didactic]* [Doctoral dissertation, Universite Lumiere Lyon 2]. https://theses.fr/2002LYO20023

Nolen, S. B. (1988). Reasons for studying: Motivational orientations and study strategies. *Cognition and Instruction, 5*(4), 269-287. https://doi.org/10.1207/s1532690xci0504_2

Oberoi, A. (2021). *Using chess as an intervention to improve executive functioning among youth* [Doctoral dissertation, College of Social and Behavioral Sciences, Walden University]. https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=12482&context=dissertations

Odhiambo, G., & Hii, A. (2012). Key stakeholders' perceptions of effective school leadership. *Educational Management Administration & Leadership, 40*(2), 232-247. https://doi.org/10.1177/1741143211432412

Oke, A., & Fernandes, F. A. P. (2020). Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th industrial revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity, 6*(2), 31. https://doi.org/10.3390/joitmc6020031

Olivo, I., & Barbaranelli, C. (2023). Checking your chess! Development and validation of the Chess Self-Efficacy Scale in a competitive setting. *TPM: Testing, Psychometrics, Methodology in Applied Psychology, 30*(3), 303-318. https://doi.org/10.4473/TPM30.3.4

Omori, M., & Tadepalli, P. (2024). Chess rating estimation from moves and clock times using a cnn-lstm. In M. Hartisch, C. H. Hsueh & J. Schaeffer (Eds.), Computers and Games. CG 2024 2024: Lecture notes in computer science (vol. 15550). Springer. https://doi.org/10.1007/978-3-031-86585-5_1

Ong, J., Bilalić, M., & Vaci, N. (2024). *Sparse but strategic: Quantitative insights into chess middlegame complexity.* https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.21203%2Frs.3.rs-

5574128%2Fv1?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InByb2ZpbGUiLCJwYWdlIjoicHVibGljYXRpb24iLCJwb3NpdGlvbiI6InBhZ2VDb250ZW50In19

Ortiz-Pulido, R., Ortiz-Pulido, R., García-Hernández, L. I., Pérez-Estudillo, C. A., & Ramírez-Ortega, M. L. (2019). Neuroscientific evidence support that chess improves academic performance in school. *Revista Mexicana de Neurociencia, 20*(4), 194-199. https://doi.org/10.24875/rmn.m19000060

Panaoura, A., & Philippou, G. (2003). The construct validity of an inventory for the measurement of young pupils' metacognitive abilities in mathematics. *International Group for the Psychology of Mathematics Education.* Paper presented at the 27th International Group for the Psychology of Mathematics Education Conference Held Jointly with the 25th PME-NA Conference (Honolulu, HI, Jul 13-18, 2003), vol. 3 pp, 437-444. https://files.eric.ed.gov/fulltext/ED501054.pd

Pearce, J., & Husbands, C. (2012). *What makes great pedagogy? Nine claims from research*. National College for School Leadership. https://assets.publishing.service.gov.uk/media/5a7e413c40f0b6230268a2a3/what-makes-great-pedagogy-nine-claims-from-research.pdf

Pearson, T. R. (2010). *The effects of learning to play chess on the nonverbal reasoning abilities of grade 5 students* [Dissertation, Library and Archives Canada= Bibliothèque et Archives Canada, Ottawa]. https://bac-lac.on.worldcat.org/oclc/728824427?lang=en&q=The%20effects%20of%20learning%20to%20play%20chess%20on%20the%20nonverbal%20reasoning%20abilities%20of%20grade%205%20students

Peng, H. (2024). The implications of artificial intelligence for management decision-making innovativeness: Insights from contemporary chess practice 1. *Journal of Innovation Economics & Management, 45*, 217-245. http://dx.doi.org/10.3917/e.jie.045.0217

Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological Bulletin, 144*(1), 48-76. https://doi.org/10.1037/bul0000124Peng, P., & Kievit, R. A. (2020). The development of academic achievement and cognitive abilities: A bidirectional perspective. *Child Development Perspectives, 14*(1), 15-20. https://doi.org/10.1111/cdep.12352

Peran, S. (2019). Five chess positions to learn law and legal argumentation. *European Journal of Educational Sciences, 6*(1), 142-160. https://doi.org/10.19044/ejes.v6no1a8

Perkins, D. N., & Salomon, G. (1992). Transfer of learning. In T. Husén & T. N. Postlethwaite (Eds.), *The international encyclopedia of education*, (vol. 2, pp. 6452-6457). Pergamon.

Petallo, D. G., & Berry, E. B. (2024). Evaluating the effectiveness of chess-based instructional materials in improving students' understanding of species diversity: A quantitative study. *International Journal of Progressive Research in Engineering Management and Science, 4*(12), pp. 2079-2084. https://www.doi.org/10.58257/IJPREMS37963

Peterson, A., Dumont, H., Lafuente, M., & Law, N. (2018). *Understanding innovative pedagogies: Key themes to analyse new approaches to teaching and learning (OECD Education Working Paper No. 172).* https://doi.org/10.1787/9f843a6e-en

Pfoertner, P. D., & Hristova, P. (2024). *Event segmentation in chess.* In Proceedings of the annual meeting of the Cognitive Science Society (vol. 46). https://escholarship.org/uc/item/3js6h99b

Phillips, D. C., & Burbules, N. C. (2000). *Postpositivism and educational research.* Rowman & Littlefield.

Phillips, R. (2003). *Stakeholder theory and organizational ethics*. Berrett-Koehler Publishers.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), Handbook of self-regulation (pp. 451–502). Academic Press.

Poston, D. I., & Vandenkieboom, K. K. (2019). The effect of chess on standardized test score gains. *SAGE Open, 9*(3). https://doi.org/10.1177/2158244019870787

Poulidis, S., Ge, H., Bastani, H., & Bastani, O. (2025). *Action vs. attention signals for human-AI collaboration: Evidence from chess.* https://ssrn.com/abstract=5128584 or http://dx.doi.org/10.2139/ssrn.5128584

Pozzi, L., Guerini, S., Arrigoni, S., Pedrocchi, A., & Gandolla, M. (2024). A robotic assistant for disabled chess players in competitive games. *International Journal of Social Robotics, 16*(1), 173-183. https://doi.org/10.1007/s12369-023-01069-y

Purnomo, A., Sandi, M., & Santoso, D. A. (2024). Analysis of stress levels in chess games. *PIALA: Journal of Sports, 1*(1), 1-10. https://jurnal.sekawansiji.org/index.php/piala/article/view/24/22

Quchqorivich, K. U. (2022). Innovative methods of evaluating logical thinking and personal qualities of primary class pupils in the process of chess teaching. *Berlin Studies Transnational Journal of Science and Humanities, 2*(1.5 Pedagogical sciences).

Ramos, L., Arán Filippetti, V., & Krumm, G. (2018). Funciones ejecutivas y práctica de ajedrez: Un estudio en niños escolarizados [Executive functions and playing chess practice: A study conducted with schoolchildren]. *Psicogente, 21*(39), 25-34. https://doi.org/10.17081/psico.21.39.2794

Rello, L., Subirats, S., & Bigham, J. P. (2016). An online chess game designed for people with dyslexia. In *Proceedings of the 13th International Web for All Conference (W4A '16)* (Article 28). Association for Computing Machinery. https://doi.org/10.1145/2899475.2899479

Rice, M., Moser, C., & Aworuwa, B. (2012). *A study of impact of learning to play online chess on 7th graders' mathematics achievement, self-regulated learning, and attitude toward math.* ITED 530.01W – Research in Instructional

Technology Texas A&M-Texarkana. https://www.chessedu.org/wp-content/uploads/Study_Learning_Chess-1.pdf

Rifner, P. J. (1992). *Playing chess: A study of the transfer of problem-solving skills in students with average and above average intelligence* [Doctoral dissertation, Purdue University]. https://docs.lib.purdue.edu/dissertations/AAI9314070/

Rimban, E. (2023). Chess strategy and the development of constructivist thinking: Cultivating cognitive skills and transferable competencies. https://ssrn.com/abstract=4490147 or http://dx.doi.org/10.2139/ssrn.4490147

Robinson, P. (2012). Abilities to learn: Cognitive abilities. In N. M. Seel (Eds.), *Encyclopedia of the sciences of learning* (pp. 17-21). Springer.

Rodríguez-Muṇiz, L. J., Rodríguez-Suárez, L., & Muṇiz-Rodríguez, L. (2022). Subjective probability in use: Reasoning about a chess game. In *Twelfth Congress of the European Society for Research in Mathematics Education (CERME12) (pp.hal-03754713)*. https://hal.science/hal-03754713v1/document

Romanova, I., Vasylieva, M., & Podberezskyi, M. (2018). Chess therapy as a new trend in training of future social pedagogues. *Journal of Physical Education and Sport, 18*, 1820-1825. https://doi.org/10.7752/jpes.2018.s4266

Rosholm, M., Mikkelsen, M. B., & Gumede, K. (2017). Your move: The effect of chess on mathematics test scores. *PloS One, 12*(5), e0177257. https://doi.org/10.1371/journal.pone.0177257

Ruben, M., Srbuhi, G., Vladimir, K., Alla, D., & Asya, B. (2019). Typical expression of cognitive dissonance and consonance in the course of argumentation among primary-school children playing chess. *Wisdom, 2*(13), 75-84. https://doi.org/10.24234/wisdom.v13i2.281

Ruiz, F. J., & Luciano, C. (2012). Improving international-level chess players' performance with an acceptance-based protocol: Preliminary findings. *The Psychological Record, 62*(3), 447-462. https://doi.org/10.1007/BF03395813

Ruoss, A., Delétang, G., Medapati, S., Grau-Moya, J., Li, K., Catt, E., Genewein, T. (2025). Amortized planning with large-scale transformers: A case study on chess. *Advances in Neural Information Processing Systems, 37*, 65765-65790. https://doi.org/10.48550/arXiv.2402.04494

Saariluoma, P. (1992). Visuospatial and articulatory interference in chess players' information intake. *Applied Cognitive Psychology, 6*(1), 77-89. https://doi.org/10.1002/acp.2350060105

Sala, G., Aksayli, N. D., Tatlidil, K. S., Tatsumi, T., Gondo, Y., Gobet, F., Verkoeijen, P. (2019). Near and far transfer in cognitive training: A second-order meta-analysis. *Collabra: Psychology, 5*(1). https://doi.org/10.1525/collabra.203

Sala, G., & Gobet, F. (2016). Do the benefits of chess instruction transfer to academic and cognitive skills? A meta-analysis. *Educational Research Review, 18*, 46-57. https://doi.org/10.1016/j.edurev.2016.02.002

Sala, G., & Gobet, F. (2017a). Does chess instruction improve mathematical problem-solving ability? Two experimental studies with an active control group.

Learning & Behavior, 45(4), 414-421. https://doi.org/10.3758/s13420-017-0280-3

Sala, G., & Gobet, F. (2017b). Far Transfer: Does it Exist? *Cognitive Psychology, 31*, 1-40.

Sala, G., & Gobet, F. (2017c). Does far transfer exist? Negative evidence from chess, music, and working memory training. *Current Directions in Psychological Science, 26*(6), 515-520. https://doi.org/10.1177/0963721417712760

Sala, G., & Gobet, F. (2018). Cognitive training does not enhance general cognition. *Trends in Cognitive Sciences, 23*(1), 9-20. https://doi.org/10.1016/j.tics.2018.10.004

Sala, G., Gobet, F., Gorini, A., & Pravettoni, G. (2015). Mathematical problem-solving abilities and chess. *SAGE Open, 5*(3). https://doi.org/10.1177/2158244015596050

Sala, G., Gobet, F., Trinchero, R., & Ventura, S. (2016). Does chess instruction enhance mathematical ability in children? A three-group design to control for placebo effects. In *Proceedings of the Annual Meeting of the Cognitive Science Society.* https://escholarship.org/uc/item/2d0454fm

Salmi, S. (2024). *Introducing a new sharpness factor to evaluate chess openings* [Masters dissertation, Dalarna University, Sweden]. https://go.exlibris.link/lzt6YxRg

Sargsyan, V., & Gharakhanyan, L. (2024). Elementary school students' reflections on chess learning difficulties. *Main Issues of Pedagogy and Psychology, 11*(2), 172-183. https://doi.org/10.24234/miopap.v11i2.43

Sari-Sarraf, V., Vakili, J., Tabatabaei, S. M., & Golizadeh, A. (2024). The brain function promotion by modulating the power of beta and gamma waves subsequent twelve weeks' time pressure training in chess players. *Journal of Applied Health Studies in Sport Physiology*. https://doi.org/10.22049/jahssp.2024.29522.1639

Schmid, L., Maag, J., Cieliebak, S. P. D. M., & von Däniken, P. (2024). Optimizing language models for chess: The impact of custom notation and Elo-based fine-tuning [Bachelor's dissertation, CAI Centre for Artificial Intelligence, Winterthur, Switzerland]. https://www.zhaw.ch/storage/engineering/institute-zentren/cai/studentische_arbeiten/Spring_2024/BA24_ciel_Schmid_Maag_Chess_with_GPT_v1.1.pdf

Schneider, W., Gruber, H., Gold, A., & Opwis, K. (1993). Chess expertise and memory for chess positions in children and adults. *Journal of Experimental Child Psychology, 56*(3), 328-349. https://doi.org/10.1006/jecp.1993.1038

Scholz, M., Niesch, H., Steffen, O., Ernst, B., Loeffler, M., Witruk, E., & Schwarz, H. (2008). Impact of chess training on mathematics performance and concentration ability of children with learning disabilities. *International Journal of Special Education, 23*(3), 138-148. https://files.eric.ed.gov/fulltext/EJ833690.pdf

Schuster, C., Stebner, F., Leutner, D., & Wirth, J. (2020). Transfer of metacognitive skills in self-regulated learning: An experimental training study. *Metacognition and Learning, 15*(3), 455-477. https://doi.org/10.1007/s11409-020-09237-5

Scott, D. (2007). Resolving the quantitative–qualitative dilemma: A critical realist approach. *International Journal of Research & Method in Education, 30*(1), 3-17. https://doi.org/10.1080/17437270701207694

Sepúlveda-Herrera, C., & Huincahue, J. (2024). The practice of chess players as a socio-cultural expression for research in ethnomathematics - a proposal in development. *Journal of Systemics, Cybernetics and Informatics, 22*(2), 27-31. https://doi.org/10.54808/JSCI.22.02.27

Shahar, G., & Avital, P. (2020). Pièce touchée!¤: The relationship between chess-playing experience and inhibition. *Psychology in Russia: State of the Art, 13*(1), 133-146. https://doi.org/10.11621/pir.2020.0111

Shannon, C. E. (1950). XXII. Programming a computer for playing chess. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 41*(314), 256-275. https://doi.org/10.1080/14786445008521796

Siegler, R. S. (1998). *Emerging minds: The process of change in children's thinking*: Oxford University Press.

Sigirtmac, A. D. (2012). Does chess training affect conceptual development of six-year-old children in Turkey? *Early Child Development and Care, 182*(6), 797-806. https://doi.org/10.1080/03004430.2011.582951

Sigirtmac, A. D. (2016). An investigation on the effectiveness of chess training on creativity and theory of mind development at early childhood. *Educational Research and Reviews, 11*(11), 1056-1063. https://doi.org/10.5897/ERR2016.2676

Simon, H. A. (1983). Discovery, invention, and development: Human creative thinking. *Proceedings of the National Academy of Sciences of the United States of America, 80*(14), 4569-4571. https://doi.org/10.1073/pnas.80.14.4569

Simon, H. A. (1986). *The role of attention in cognition*: Academic Press.

Simon, H. A, & Chase, W. (1988). Skill in chess. In D. Levy (Eds.), *Computer chess compendium* (pp. 175-188). Springer.

Simon, H. A., & Newell, A. (1971). Human problem solving: The state of the theory in 1970. *American Psychologist, 26*(2), 145-159. https://doi.org/10.1037/h0030806

Simon, H. A., & Simon, P. A. (1962). Trial and error search in solving difficult problems: Evidence from the game of chess. *Behavioral Science, 7*(4), 425-429. https://doi.org/10.1002/bs.3830070402

Singh, S. (2023). Chess and the human brain - demystifying the therapeutic value of a board game. *Journal of High School Science, 7*(3). https://doi.org/10.64336/001c.84175

Singh, Y. R., Kadam, S. S., & Mital, A. (2023). *A case control study to assess and compare cognitive functions among chess players and non-chess players aged 11 to 16 years in Western India.* https://www.researchsquare.com/article/rs-3493568/v1 https://doi.org/10.21203/rs.3.rs-3493568/v1

Siven, A. (2024). Systematic analysis of the evolution of chess computers [Bachelor's dissertation, Lahti University of Technology, Finland]. https://lutpub.lut.fi/bitstream/10024/168185/1/bachelorthesis_siven_artturi.pdf

Smerdon, D., Hu, H., McLennan, A., von Hippel, W., & Albrecht, S. (2020). Female chess players show typical stereotype-threat effects: Commentary on Stafford (2018). *Psychological Science, 31*(6), 756-759. https://doi.org/10.1177/0956797620924051

Smerdon, D., Meyer, C., Reizniece-Ozola, D., Rodrigo-Yanguas, M., & Sorokina, A. (2023). *Report: 2023 FIDE Gender Equality in Chess Index (GECI).* FIDE; The University of Queensland. https://doi.org/10.14264/9bb291f

Smith, E. (2021). *Talking chess: A phenomenological study of strategy and social reasoning in chess players* [Doctor of Philosophy dissertation, School of Social and Behavioral Sciences, Northcentral University]. https://www.proquest.com/openview/9fd3e2b27012e765c99c87e5d7f8e58f/1?pq-origsite=gscholar&cbl=18750&diss=y

Smith, E. T., Bartlett, J. C., Krawczyk, D. C., & Basak, C. (2021). Are the advantages of chess expertise on visuo-spatial working-memory capacity domain specific or domain general? *Memory & Cognition, 49*(8), 1600-1616. https://doi.org/10.3758/s13421-021-01184-z

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology, 35*(1), 4-28. https://doi.org/10.1006/jesp.1998.1373

Stafford, T. (2017). Female chess players outperform expectations when playing men. *Psychological Science, 29*. https://doi.org/10.1177/0956797617736887

Steele, C. M., Spencer, S. J., & Aronson, J. (2002). Contending with group image: The psychology of stereotype and social identity threat. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (vol. 34, pp. 379-440). Academic Press.

Stegariu, V.-I., & Abalasei, B. (2022b). Correlation between attentional abilities and spatial orientation in children who study chess in school. *Revista Romaneasca pentru Educatie Multidimensionala, 14*(3), 126-138. https://doi.org/10.18662/rrem/14.3/601

Stegariu, V., Abalașei, B., Hakman, A., & Medvid, A. (2022). Comparative study of the evolution of attentional abilities in two classes from primary cycle in which chess is studied. https://doi.org/10.32843/2663-6085/2022/44/3.31

Stegariu, V. I., Abalasei, B. A., Onose, R. M., & Popescu, L. (2023). A study on the correlation between intelligence and spatial orientation in children who practice chess at school. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 14*(4), 458-478. https://doi.org/10.18662/brain/14.4/516

Stegariu, V. I., Abalasei, B. A., & Stoica, M. (2022). A study on the correlation between intelligence and body schema in children who practice chess at school. *Children, 9*(4), 477. https://doi.org/10.3390/children9040477Stegariu, V. I., Condrea, C. C., Astanei, C. M., & Abalașei, B. A. (2025). The effect of chess training and well-being workshops on vulnerable children: A dual assessment of cognitive and emotional growth. *BRAIN: Broad Research in Artificial Intelligence and Neuroscience, 16*(1), 337-351. http://dx.doi.org/10.70594/brain/16.1/25

Stegariu, V.-I., & Iacob, G. S. (2020). The effects of practising chess on analytical thinking in primary school students. *Sport and Society, 20*(2). https://doi.org.10.36836/2020/2/7

Stegariu, V., & Iacob, G. (2022a). Study on the correlation between spatial orientation and logical thinking in students who study chess in school. *Bulletin of the Transilvania University of Braşov. Series IX: Sciences of Human Kinetics*, 217-222. http://dx.doi.org/10.31926/but.shk.2021.14.63.2.26

Stegariu, V., Popușoi, S. A., Abălașei, B., Voinea, N. L., Stelescu, I. D., Trofin, F. P., & Honceriu, C. (2019). The Role of chess in the intellectual development of childrens from primary school. *Sport & Society/Sport si Societate, 19*(2). https://doi.org/10.36836/UAIC/FEFS/10.60Sternberg, R. J., Kaufman, J. C., & Grigorenko, E. L. (2008). *Applied intelligence*: Cambridge University Press.

Sundaramadhavan, M. T., De la Cruz, L. B., Barbier, A., Whatley, S., & Megrahi, M. (2021). *The joy of rediscovering chess: The perspectives of dialogic thinking in chess.* Paper presented at the European Conference on Games Based Learning. http://dx.doi.org/10.34.190/GBL.21.061

Sungur, S., & Senler, B. (2009). An analysis of Turkish high school students' metacognition and motivation. *Educational Research and Evaluation, 15*(1), 45-62. https://doi.org/10.1080/13803610802591667

Szczepanik-Ninin, M. (2024). Chess as a pedagogical tool. *The Person and the Challenges: The Journal of Theology, Education, Canon Law and Social Studies Inspired by Pope John Paul II, 14*(2), 199-212. http://dx.doi.org/10.15633/pch.14213

Szczepańska, A., & Kaźmierczak, R. (2022). The theoretical model of decision-making behaviour geospatial analysis using data obtained from the games of chess. *International Journal of Environmental Research and Public Health, 19*(19), 12353. https://doi.org/10.3390/ijerph191912353

Tabachnick, B. G., & Fidell, L. S. (2007). *Experimental designs using ANOVA* (vol. 724). Thomson/Brooks/Cole Belmont, CA. https://sdan.sites.umassd.edu/files/2023/01/Experimental-designs-using-ANOVA.pdf

Tachie, S. A., & Ramathe, J. M. (2022). Metacognition application: The use of chess as a strategy to improve the teaching and learning of mathematics. *Education Research International,* 6257414. https://doi.org/10.1155/2022/6257414

Teimoory, N. (2022). The comparison effectiveness of mindfulness based stress reduction and acceptance and commitment therapy on anxiety and executive function in professional adolescents chess player. *Journal of Clinical Sport Neuropsychology, 2*(3). http://jcsnp.ir/article-1-24-en.html

Tenemaza Kramaley, D., & Wishart, J. (2020). Can fixed versus growth mindset theories of intelligence and chess ability, together with deliberate practice, improve our understanding of expert performance? *Gifted Education International, 36*(1), 3-16. https://doi.org/10.1177/0261429419864272

Thakur, S., Shinde, S., Shirurkar, O., Sarwade, S., Singh, N., & Dhakulkar, B. (2024). *Designing a next-generation chess engine with advanced AI and neural networks.*

Thompson, M. J. (2003). Does the playing of chess lead to improved scholastic achievement? *Issues in Educational Research, 13*(2), 3-26. http://www.iier.org.au/iier13/thompson.html

Tirado, A., & Pilatti, L. (2024). Beyond pieces: Role of AI in chess strategy precision. https://doi.org/10.21203/rs.3.rs-5213479/v1

Tirado, A., & Pilatti, L. (2024). Integration of the scientific method in chess teaching. *Main Issues of Pedagogy and Psychology, 11*(2), 61-83. https://doi.org/10.24234/miopap.v11i2.32

Trevino, N. (2019). *How chess relates to theory of mind* [Masters dissertation, University of Texas]. https://scholarworks.utrgv.edu/cgi/viewcontent.cgi?article=1582&context=etd

Trevisan, N., Jaillard, A., Cattarinussi, G., De Roni, P., & Sambataro, F. (2022). Surface-based cortical measures in multimodal association brain regions predict chess expertise. *Brain Sciences, 12*(11), 1592. https://doi.org/10.3390/brainsci12111592

Trinchero, R., & Sala, G. (2016). Chess training and mathematical problem-solving: The role of teaching heuristics in transfer of learning. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(3), 655-668. https://doi.org/10.12973/eurasia.2016.1255a

Unterrainer, J. M., Kaller, C. P., Halsband, U., & Rahm, B. (2006). Planning abilities and chess: A comparison of chess and non-chess players on the Tower of London task. *British Journal of Psychology, 97*(3), 299-311. https://doi.org/10.1348/000712605X71407

Uskoković, V. (2024). Teaching chess history to students in natural sciences: How to do it and why. *Substantia.* https://doi.org/10.36253/Substantia-2479

Uskoković, V. (2023). Natural sciences and chess: A romantic relationship missing from higher education curricula. *Heliyon*. https://doi.org/10.1016/j.heliyon.2023.e15015

Vaci, N., & Bilalić, M. (2017). Chess databases as a research vehicle in psychology: Modeling large data. *Behavior Research Methods, 49*, 1227-1240. https://doi.org/10.3758/s13428-016-0782-5

Varga, A., & Marschalko, E. E. (2024). The role of emotionality, self-efficacy, rational- and intuitive-thinking styles in advanced chess expertise. *Studia Universitatis Babes-Bolyai, Psychologia-Paedagogia, 69*(1). https://doi.org/10.24193/subbpsyped.2024.1.07

Veenman, M. V., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences, 15*(2), 159-176. https://doi.org/10.1016/j.lindif.2004.12.001Veenman, M. V., Wilhelm, P., & Beishuizen, J. J. (2004). The relation between intellectual and metacognitive skills from a developmental perspective. *Learning and instruction, 14*(1), 89-109. https://psycnet.apa.org/doi/10.1016/j.learninstruc.2003.10.004

Velea, T., & Cojocaru, V. (2018). The effect of playing chess on focused attention. *The European Proceedings of Social & Behavioural Sciences*, 685-690. http://dx.doi.org/10.15405/epsbs.2019.02.84

Velea, T., & Cojocaru, V. (2019). A new perspective of teaching chess to kids. In V. Grigore, M. Stănescu, M. Stoicescu, & L. Popescu (Eds.), *Education and sports science in the 21st century (vol.55) (European proceedings of social and behavioural sciences)* (pp. 138-144). Future Academy.

Vollstädt-Klein, S., Grimm, O., Kirsch, P., & Bilalić, M. (2010). Personality of elite male and female chess players and its relation to chess skill. *Learning and Individual Differences, 20*(5), 517-521. https://psycnet.apa.org/doi/10.1016/j.lindif.2010.04.005

Wang, S., Ji, L., Wang, R., Zhao, W., Liu, H., Hou, Y., & Wu, Y. N. (2024). Explore the reasoning capability of LLMs in the chess testbed. *arXiv preprint arXiv:2411.06655*. https://doi.org/10.48550/arXiv.2411.06655

Waters, A. J., & Gobet, F. (2008). Mental imagery and chunks: Empirical and computational findings. *Memory & Cognition, 36*, 505-517. https://doi.org/10.3758/MC.36.3.505

Waters, A. J., Gobet, F., & Leyden, G. (2002). Visuospatial abilities of chess players. *British Journal of Psychology, 93*(4), 557-565. https://doi.org/10.1348/000712602761381402

Weitl-Harms, S., Hastings, J., & Powell, J. (2024). *Toward automated knowledge discovery in case-based reasoning.* In *The International FLAIRS Conference Proceedings, 37*(1). https://doi.org/10.32473/flairs.37.1.135434

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*(2), 89-100. https://doi.org/10.1111/j.1469-7610.1976.tb00381.x

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249-265. https://doi.org/10.1037/a0031311

Xalilovich, T. M. (2023). Pedagogical necessity of developing intellectual abilities of schoolchildren during chess teaching. *Web of Synergy: International Interdisciplinary Research Journal, 2*(4), 742-

747. https://journal.univerpublishing.org/index.php/synergy/article/view/1237/1065

Zapounidis, T. (2021). Young learners, Maths, EFL and chess: With CLIL they all progress. *Research Papers in Language Teaching & Learning, 11*(1), 150-158.

Zaretsky, V., Gilyazov, A., Glukhova, O., Gordon, M., & Muksimova, M. (2023). Chess for Overall Development project: History and experience. *Main Issues of Pedagogy and Psychology, 2*(10), 46-58. https://doi.org/10.24234/miopap.v2i10.7

Zikmund, W. G., Babin, B. J., Carr, J., & Griffin, M. (2003). Research methods. *Health Economics Research Method, 2*(3), 56-79.

Appendix A: University of Southern Queensland Ethics Approval

University of Southern Queensland

Office of Research
Human Research Ethics Committee
human.ethics@usq.edu.au

04/09/2023
Mr Graeme Gardiner (Student)
Australia

Dear Graeme

Re: UniSQ HREC Final report acceptance notification

Thank you for submitting your final report to the University of Southern Queensland Human Research Ethics Committee(UniSQ HREC) for consideration. The Committee has reviewed and assessed the final report as satisfactory. Based on this final report, the project has been recorded as complete.
Project ID: ETH2023-0490
Project title: Investigating the relationship between Chess Ratings and Standardised Testing: A quantitative study of Queensland school students
The project records must be available for audit by UniSQ, the UniSQ HREC, and any authorised external reviewers during the retention period.
Research data must be retained for the required period in accordance with the University sector retention and disposal schedule (refer section 8. Research [601.2/F8]), and the Australian Code for the Responsible Conduct of Research (refer section 2 of the Code). To enable researchers to increase research impact and comply with good practice of research data management, UniSQ provides research data storage solutions and a research data management plan guide. Please contact eResearch Services for further information.

If you have any questions, please do not hesitate to contact the UniSQ HREC Executive Officer (human.ethics@usq.edu.au).

Yours sincerely

UniSQ Human Research Ethics Committee

Ethics ETH2023-0490 (HREC)(Milestone): Mr Graeme Gardiner (Student)

1. QJRL Ethical Approval

Attention:

Assoc Prof Luke van der Laan

Dr David Smerdon

Graeme Gardiner

23 August 2020

Re USQ Research Project: Investigating the relationship between Chess Ratings and Standardised Testing: A quantitative study of Queensland school students

We the undersigned approve the use of historical data from the Queensland Junior Ratings List through to January 2020 for the above-mentioned research project, subject to ethical approval from USQ Ethics Department.

We note the advice to those on the list given at

https://gardinerchess.com.au/wp-content/uploads/2020/05/QJRL-FAQs-for-playersparents-2020.pdf

'Data from the list may be used for research purposes to university researcher(s) subject to data being de-personalised prior to analysis and ethical approval being provided by that institution'.

Sincerely,

Dr David McKinnon (list owner)

24.8.20

Mr Mark Stokes (endorsement by President of Chess Association of Queensland)

M Stokes 24.8.20

Appendix B: Studies Relating to Children Learning Chess and Possible Resulting Cognitive Benefits Excluding Mathematics and Reading

Table 30: Studies Relating to Children Learning Chess and Possible Resulting Cognitive Benefits Excluding Mathematics and Reading

Author	**Year**	**Country of Origin**	**School Level (S)** High (H); Primary (P); Both (B)	**Chess Playing Level (C)** Beginner (B); Intermediate (I); Advanced (A)	**Intervention (I)** Maths (M); Reading (R); Both (B); Other (O)	**Population Size (P)**	**Testing Methodology (T)**	**Notes/Key Findings**
Ferguson	**1986**	U.S.A.	H	A	O	94	Torrance and Watson-Glaser	Tests for critical and creative thinking, significant findings
Fried and Gingburg (U/P)	**1987**	U.S.A.	P	B	O	30	WISC-R, ANOVAS	No significant findings
Horgan and Morgan	**1990**	U.S.A.	B	A	O	113	Correlations; R.P.M. (I.Q.)	74 players rated under 1000, 39 over. Elite players scored above average on R.P.M.
Celone	**2001**	U.S.A.	B	B	M	19	TONI-3	Treatment group of 19 scored significant increases in Abstract Reasoning and Problem Solving measured by TONI-3.
Thompson	**2003**	Australia	H	B-A	O	508	Rasch Scaling Hierarchical Linear Modelling	There is no support for the hypothesis that playing chess improves scholastic achievement in science tests (Australian Schools Science Competition).
Fernandez Amigo	**2008**	Spain	P	B	M	144	EFAI Logical Reasoning and Numerical Calculation	Chess group 71; Control group 73. There was a significant result in favour of the chess group.
Amelkina and Ala	**2009**	Lithuania	H	B	O	116	Torrance Test of Creative Thinking and Ravens (I.Q.)	Chess group 56; Control 60. Positive results for both I.Q. and creative thinking.
Erhan et al.	**2009**	Turkey	B	B	O	90	P.C.E. T-Tests	Chess group 45; Control 45. Statistically significant results for the chess group in problem-solving.

Author	Year	Country of Origin	School Level (S) High (H); Primary (P); Both (B)	Chess Playing Level (C) Beginner (B); Intermediate (I); Advanced (A)	Intervention (I) Maths (M); Reading (R); Both (B); Other (O)	Population Size (P)	Testing Methodology (T)	Notes/Key Findings
Pearson	**2010**	Canada	P	B	O	53	CFIT T-Tests and Linear Regressions	Test of nonverbal reasoning. Chess group 31; Control group 22. Significant positive impact on non-verbal reasoning abilities.
Sigirtmac	**2012**	Turkey	P	B	O	100	Mann-Whitney U Test T-Tests	Chess group 50; control group 50. The spatial concept test revealed a statistically meaningful difference in all concepts favouring the chess group—six-year-olds.
Cabot-Thibault	**2013**	Canada	H	B	O	122	MRT MANCOVA	Chess Group 71; Control Group 51. There was a significant result in favour of the chess group on the Mental Rotation Test of Spatial Ability.
Basson	**2015**	South Africa	P	B	O	64	JSAIS IQ test ANOVA and MANOVA	Five and 6-year-olds. Chess group 34; Control group 30. Small significantly significant result in favour of the chess group for I.Q. scores.
Mashuri	**2015**	Indonesia	P	B	O	30	T-Tests Academic Report cards	It needs to be clarified if the 30 is just the chess group or the total population of the study. The authors claim that chess has a significant effect on academic achievement. The paper should have included statistical details.
Sigirtmac	**2016**	Turkey	P	B	O	87	T.O.M. and TTCT T-Tests.	Chess group 41, control group 46. Average age 5.5 years. Statistically significant result for the chess group in a test of creative thinking.
Lammers	**2016**	South Africa	P	B	O	80	SON-R IQ Test ANOVA T-Tests	Chess group 36; Other activities control group 22; do nothing control group 22. Average age 12. Significant result in favour of the chess group.

Author	Year	Country of Origin	School Level (S) High (H); Primary (P); Both (B)	Chess Playing Level (C) Beginner (B); Intermediate (I); Advanced (A)	Intervention (I) Maths (M); Reading (R); Both (B); Other (O)	Population Size (P)	Testing Methodology (T)	Notes/Key Findings
Grau-Pérez and Moreira	**2017**	Uruguay	P	B-I	O	28	RPM Test TOL Planning Test WCST Card Sorting Test	Chess group 14; Control group 14. Average age 10.5. The authors claim that the results add to existing evidence that instruction and practice of chess stimulate planning and impulse control skills.
Joseph et al.	**2017**	India	P	B	O	63	WKCT Creativity Test T-Tests	Chess group 31 volunteered; Control group randomly selected did other activities 32. Average age 12. Significant result for improved creative thinking skills in the chess group.
Ramos et al.	**2018**	Argentina	P	B	O	65	MANOVA FE WISC	Chess group 35; Control group 30; age 8-12. Significant result for the chess group about executive functions: working memory, inhibition, cognitive flexibility and planning.
Joseph et al.	**2018**	India	B	B	O	86	BKTI Paired T-Tests and Regressions I.Q. nonverbal reasoning	8 x groups of 4. Is there a relationship between this study and the following study by the same author?
Joseph et al.	**2018**	India	B	B	O	151	BKTI IQ Test Verbal Reasoning ANCOVA	Average age 11; Chess group 70; Control group 81. Significant increases in verbal reasoning
Gardiner	**2019**	Australia	P	B	O	203	RPM and AGAT	Children grades 1-6. There are no significant findings on R.P.M. (I.Q. scores) or AGAT (reasoning skills)—Chess Group 46, Music 48; Both 37; Neither 72.
Stegariu et al.	**2019**	Romania	P	B	O	67	S.P.M. (R.P.M.)	Children average age 8. Chess advanced group 15; Chess beginner group 21; Control Group 31. Significant result on Ravens I.Q. tests for advanced chess group.

Author	Year	Country of Origin	**School Level (S)** High (H); Primary (P); Both (B)	**Chess Playing Level (C)** Beginner (B); Intermediate (I); Advanced (A)	**Intervention (I)** Maths (M); Reading (R); Both (B); Other (O)	Population Size (P)	Testing Methodology (T)	Notes/Key Findings
Velea and Cojocaru	**2018**	Romania	P	B	O	34	Kraepelin, Bourdon-Anfimov and Toulouse-Pieron Z-Test	Children in grades 1-4, average age 8, attended a six-month chess course. Tests for focussed attention. Results showed improved concentration and focused attention.
Atashafrouz	**2019**	Iran	H	B	O	40	PSSG CWMT LASSI Tests	Chess group 20, Control group 20. Significant improvement in test scores for working memory and concentration
Joseph et al.	**2020**	India	B	B	O	178	WISC-IQ Working Memory ANCOVA	Chess group 88; Control group 90. Significant result in favour of I.Q./Working Memory
Oberoi	**2021**	U.S.A.	H	B-A	O	39	Paired-Samples T-Tests	Youths age 8-17. Unrated to USCF 1200. Significant positive difference in decision-making and working memory.
Stegariu and Iacob	**2022**	Romania	P	I	O	32	Bender-Santucci test Similarities test	Chess group 16; Control group 16. Average age 10.5. Bender-Santucci test = analytical thinking; Similarities test = spatial orientation. The chess group studied chess from grade one. There was a significant result in their favour for both analytical thinking and spatial orientation.

This table represents 27 studies from 13 countries that were omitted from the main inclusion criteria because they did not directly relate to mathematics or reading scores, but studied cognitive skills in their outcome measures. Skills measured in this table include critical thinking, creative thinking, science scores, IQ, reasoning, problem solving, spatial ability, planning, concentration, working memory and analytical thinking. This table allows readers to locate studies they may have expected in the "maths and reading" list. Otherwise, it may be a useful record for anyone interested in chess and education.

Appendix C: Descriptive Statistics

		N	Mean	Std. Deviation	Std. Error
SCALE_SCORE_GP	3	158	510.67977679065130	92.607591319006290	7.367464384380456
	5	204	587.26641851396570	76.693363140358800	5.369609449128614
	7	220	627.84676344398780	77.059816653294300	5.195371778909367
	9	214	663.96392215617880	74.516292226306130	5.093828869996019
	Total	796	603.89990126742650	96.161106496165400	3.408340052396832
SCALE_SCORE_NMCY	3	158	497.75466873032240	78.917562046888240	6.278344133579207
	5	204	606.64187691721080	82.800029973016120	5.797161646406837
	7	220	671.05807224166340	79.566316571767360	5.364359968939233
	9	215	713.26948398249740	76.691655732559740	5.230327509422403
	Total	797	631.60087264730840	110.667067067573020	3.920028636193945
SCALE_SCORE_READ	3	159	497.71034820258830	79.943477904748050	6.339930192018386
	5	204	573.30457619387140	65.536489698216880	4.588472065075997
	7	221	618.14490286452080	61.443081951931980	4.133108960835048
	9	216	647.80438259267080	55.251768394056420	3.759406665329805
	Total	800	590.78231135104660	84.284446577301520	2.979905186168260
SCALE_SCORE_SPEL	3	158	474.36007980243227	72.553125470734120	5.772016745795821
	5	204	549.93470149154340	65.695199565431660	4.599583978385976
	7	220	611.10387849324990	60.819384392043330	4.100442059221467
	9	214	648.28154220686970	59.593815863147190	4.073749386174655

	Total	796	578.27974247970380	89.8984198367983 50	3.186365009112745
SCALE_SCORE_WRIT	3	158	465.6947899	58.40656230	4.64657661
	5	203	530.6823451	58.77305007	4.12505943
	7	219	587.4111168	68.38774544	4.62121558
	9	215	625.5305067	68.21183831	4.65200876
	Total	795	559.0445112	86.31376313	3.06123371

		95% Confidence Interval for Mean		Minimum	Maximum
		Lower Bound	Upper Bound		
SCALE_SCORE_GP	3	496.12764097927370	525.23191260202900	215.800000000000	799.225880000000
	5	576.67905835423400	597.85377867369740	400.100000000000	844.300000000000
	7	617.60743708913760	638.08608979883800	439.300000000000	857.436240000000
	9	653.92315064890480	674.00469366345280	499.300000000000	932.900000000000
	Total	597.20949183022370	610.59031070462920	215.800000000000	932.900000000000
SCALE_SCORE_NMCY	3	485.35375143561420	510.15558602503063	291.300000000000	739.000000000000
	5	595.21150403140380	618.07224980301770	416.500000000000	836.900000000000
	7	660.48569460550630	681.63044987782040	481.100000000000	911.122390000000
	9	702.95992654741670	723.57904141757810	519.825850000000	920.000000000000
	Total	623.90605759292980	639.29568770168700	291.300000000000	920.000000000000
SCALE_SCORE_READ	3	485.18840233878757	510.23229406638904	250.300000000000	684.700000000000
	5	564.25739933751530	582.35175305022760	383.500000000000	772.500000000000
	7	609.99934861057280	626.29045711846870	477.000000000000	834.600000000000
	9	640.39436979116410	655.21439539417750	520.777230000000	790.700000000000
	Total	584.93294383057590	596.63167887151720	250.300000000000	834.600000000000
SCALE_SCORE_SPEL	3	462.95925487704244	485.76090472782210	292.800000000000	655.800000000000
	5	540.86561506627150	559.00378791681520	349.800000000000	708.000000000000

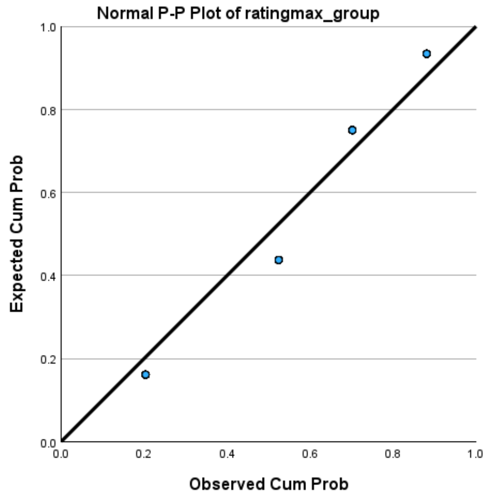
	7	603.02250025310850	619.18525673339130	438.500000000000	777.847260000000
	9	640.25151453840800	656.31156987533150	427.567930000000	835.300000000000
	Total	572.02505949631170	584.53442546309600	292.800000000000	835.300000000000
SCALE_SCORE_WRIT	3	456.5169222	474.8726577	217.40000	611.30000
	5	522.5486462	538.8160440	343.60000	678.70000
	7	578.3031372	596.5190965	402.00000	768.50000
	9	616.3608799	634.7001336	415.34784	777.90000
	Total	553.0354435	565.0535789	217.40000	777.90000

Tests of Homogeneity of Variances

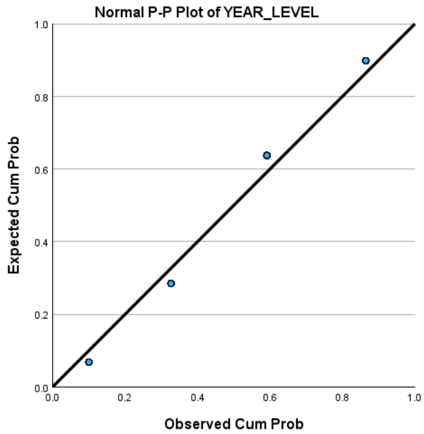
		Levene Statistic	df1	df2
SCALE_SCORE_GP	Based on Mean	2.175	3	792
	Based on Median	2.194	3	792
	Based on Median and with adjusted df	2.194	3	757.416
	Based on trimmed mean	2.192	3	792
SCALE_SCORE_NMCY	Based on Mean	.522	3	793
	Based on Median	.478	3	793
	Based on Median and with adjusted df	.478	3	789.051
	Based on trimmed mean	.505	3	793
SCALE_SCORE_READ	Based on Mean	7.612	3	796
	Based on Median	7.547	3	796
	Based on Median and with adjusted df	7.547	3	731.410
	Based on trimmed mean	7.634	3	796
SCALE_SCORE_SPEL	Based on Mean	3.390	3	792
	Based on Median	3.386	3	792
	Based on Median and with adjusted df	3.386	3	781.829
	Based on trimmed mean	3.390	3	792
SCALE_SCORE_WRIT	Based on Mean	3.727	3	791
	Based on Median	3.597	3	791
	Based on Median and with adjusted df	3.597	3	772.068
	Based on trimmed mean	3.703	3	791

Appendix D: PP-Plots

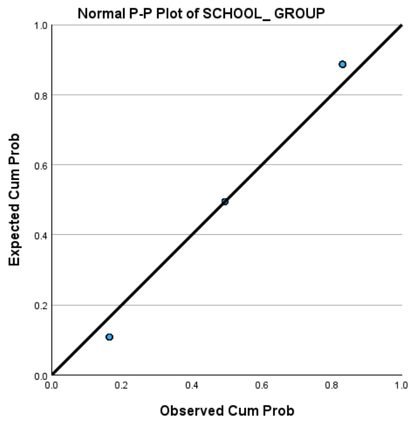
RATINGMX_GROUP



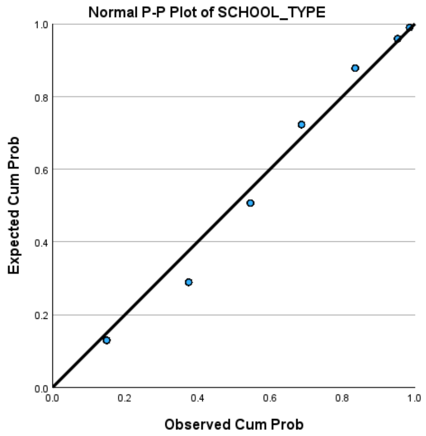
YEAR_LEVEL



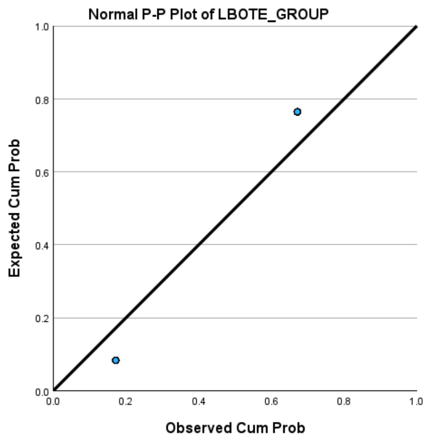
SCHOOL_ GROUP



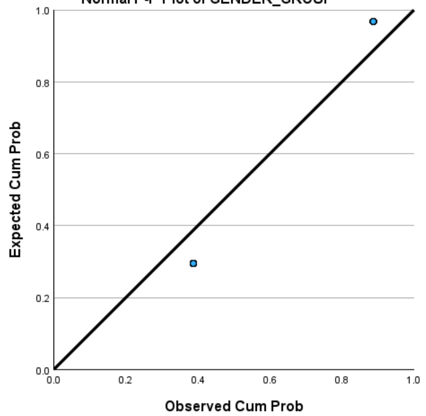
SCHOOL_TYPE



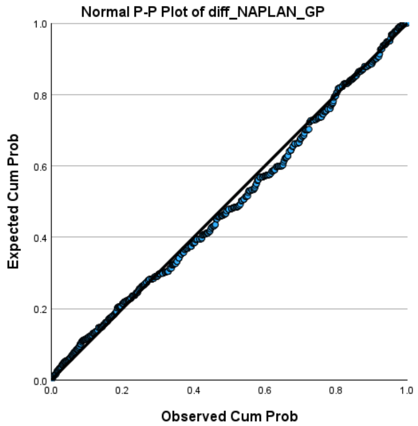
LBOTE_GROUP



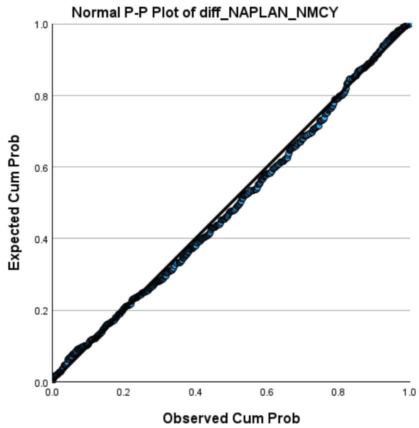
GENDER_GROUP



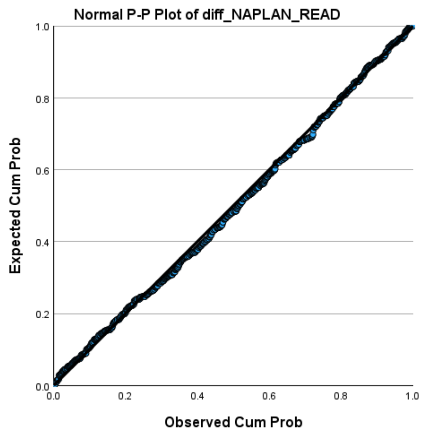
diff_NAPLAN_GP



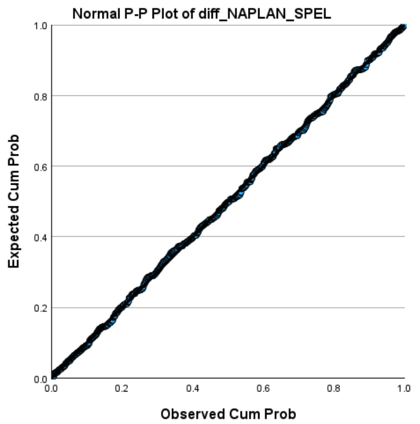
diff_NAPLAN_NMCY



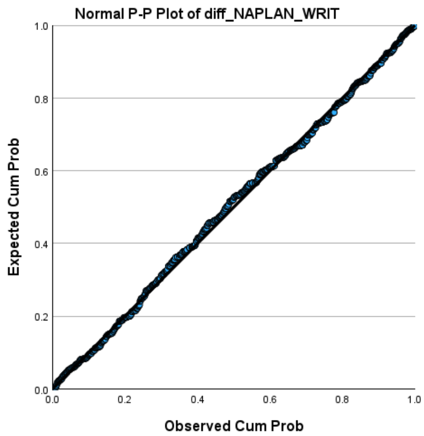
diff_NAPLAN_READ



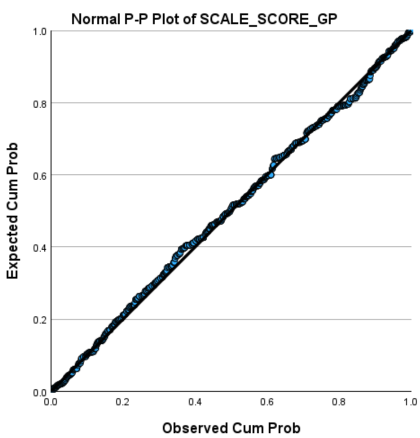
diff_NAPLAN_SPEL



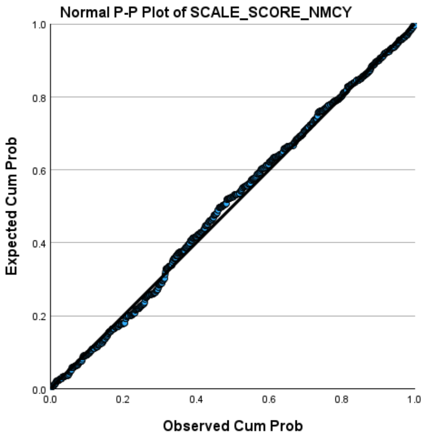
diff_NAPLAN_WRIT



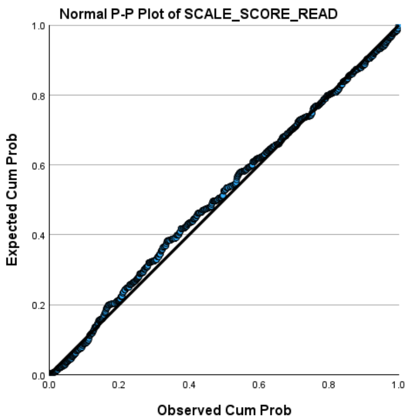
SCALE_SCORE_GP



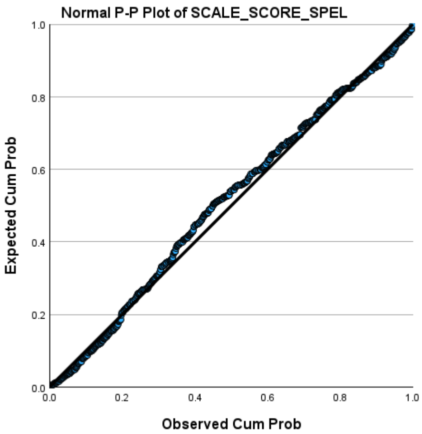
SCALE_SCORE_NMCY



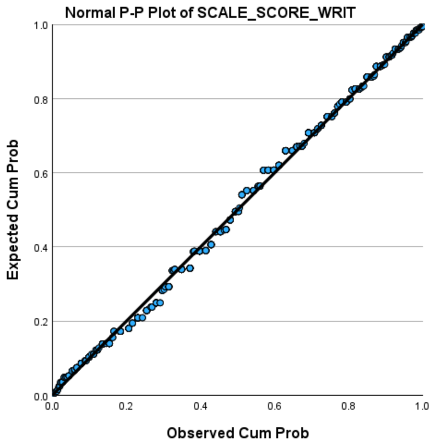
SCALE_SCORE_READ



SCALE_SCORE_SPEL



SCALE_SCORE_WRIT



Appendix E: T-Tests

T-Test

[DataSet1]

One-Sample Statistics

ratingmax_group		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_GP	321	86.642060056878500	73.383741856350300	4.095881058755850
2	diff_NAPLAN_GP	187	78.176732477382100	78.057210172788000	5.708108530365560
3	diff_NAPLAN_GP	92	100.956096341620000	84.944730831944300	8.856100388329400
4	diff_NAPLAN_GP	184	94.065816814749800	81.642669735481100	6.018777465753770

One-Sample Test

ratingmax_group		Test Value = 88.079				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_GP	-0.351	320	0.363	0.726	-1.436939943121530
2	diff_NAPLAN_GP	-1.735	186	0.042	0.084	-9.902267522617860
3	diff_NAPLAN_GP	1.454	91	0.075	0.149	12.877096341620300
4	diff_NAPLAN_GP	0.995	183	0.161	0.321	5.986816814749840

One-Sample Effect Sizes

ratingmax_group			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_GP	Cohen's d	73.383741856350300	-0.020	-0.129	0.090
		Hedges' correction	73.556296717614400	-0.020	-0.129	0.090
2	diff_NAPLAN_GP	Cohen's d	78.057210172788000	-0.127	-0.271	0.017
		Hedges' correction	78.373729686773500	-0.126	-0.270	0.017
3	diff_NAPLAN_GP	Cohen's d	84.944730831944300	0.152	-0.054	0.357
		Hedges' correction	85.652932145091500	0.150	-0.054	0.354
4	diff_NAPLAN_GP	Cohen's d	81.642669735481100	0.073	-0.071	0.218
		Hedges' correction	81.979186433850900	0.073	-0.071	0.217

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:18:45
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>

	Split File	ratingmax_group
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=115.846 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_NMCY /ES DISPLAY(TRUE) /CTERIA=CI(.95).
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.47

One-Sample Statistics

ratingmax_group		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_NMCY	320	103.410692469155000	86.678443204097800	4.845472279705430
2	diff_NAPLAN_NMCY	188	112.096760803194000	74.002296000394700	5.397172138461120
3	diff_NAPLAN_NMCY	93	126.580574698006000	69.381742711126600	7.194551568765300
4	diff_NAPLAN_NMCY	184	135.251572999242000	78.074236004918400	5.755709040932130

One-Sample Test

ratingmax_group		Test Value = 115.846				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_NMCY	-2.566	319	0.005	0.011	-12.435307530844600
2	diff_NAPLAN_NMCY	-0.695	187	0.244	0.488	-3.749239196805820
3	diff_NAPLAN_NMCY	1.492	92	0.070	0.139	10.734574698005500
4	diff_NAPLAN_NMCY	3.372	183	0.000	0.001	19.405572999241500

One-Sample Effect Sizes

ratingmax_group			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_NMCY	Cohen's d	86.678443204097800	-0.143	-0.253	-0.033
		Hedges' correction	86.882900301192500	-0.143	-0.253	-0.033
2	diff_NAPLAN_NMCY	Cohen's d	74.002296000394700	-0.051	-0.194	0.092
		Hedges' correction	74.300759286631100	-0.050	-0.193	0.092
3	diff_NAPLAN_NMCY	Cohen's d	69.381742711126600	0.155	-0.050	0.359
		Hedges' correction	69.953832749004700	0.153	-0.050	0.356
4	diff_NAPLAN_NMCY	Cohen's d	78.074236004918400	0.249	0.102	0.395
		Hedges' correction	78.396044248245600	0.248	0.101	0.393

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:20:03
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	ratingmax_group
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=75.058 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_REA D /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.09
	Elapsed Time	00:00:00.46

One-Sample Statistics

ratingmax_group		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_READ	321	73.360597667729700	59.864201795161800	3.341293916441560
2	diff_NAPLAN_READ	188	68.266764139406400	65.482529273664000	4.775804287881820
3	diff_NAPLAN_READ	93	84.386888180034800	73.335156358947500	7.604501466973140
4	diff_NAPLAN_READ	186	79.349274035185200	63.614365082522300	4.664431556633510

One-Sample Test

ratingmax_group		Test Value = 75.058				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_READ	-0.508	320	0.306	0.612	-1.697402332270300
2	diff_NAPLAN_READ	-1.422	187	0.078	0.157	-6.791235860593640
3	diff_NAPLAN_READ	1.227	92	0.112	0.223	9.328888180034800
4	diff_NAPLAN_READ	0.920	185	0.179	0.359	4.291274035185200

One-Sample Effect Sizes

ratingmax_group			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_READ	Cohen's d	59.864201795161800	-0.028	-0.138	0.081
		Hedges' correction	60.004966749007700	-0.028	-0.137	0.081
2	diff_NAPLAN_READ	Cohen's d	65.482529273664000	-0.104	-0.247	0.040

		Hedges' correction	65.746630956103600	-0.103	-0.246	0.040
3	diff_NAPLAN_READ	Cohen's d	73.335156358947500	0.127	-0.077	0.331
		Hedges' correction	73.939844433069100	0.126	-0.077	0.328
4	diff_NAPLAN_READ	Cohen's d	63.614365082522300	0.067	-0.077	0.211
		Hedges' correction	63.873721560685500	0.067	-0.076	0.210

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:21:09
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	ratingmax_group
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.

	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=62.537 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_SPE L /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.28

One-Sample Statistics

ratingmax_group		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_SPEL	321	58.886395304405200	64.216426342785500	3.584211402483080
2	diff_NAPLAN_SPEL	187	51.961075230739400	62.183588237195000	4.547314331113690
3	diff_NAPLAN_SPEL	92	72.313379664224300	54.172008238535200	5.647822278076600
4	diff_NAPLAN_SPEL	184	75.068968064528300	64.901390679282800	4.784593999463330

One-Sample Test

ratingmax_group		Test Value = 62.537				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	

1	diff_NAPLAN_SPEL	-1.019	320	0.155	0.309	-3.650604695594840
2	diff_NAPLAN_SPEL	-2.326	186	0.011	0.021	-10.575924769260600
3	diff_NAPLAN_SPEL	1.731	91	0.043	0.087	9.776379664224320
4	diff_NAPLAN_SPEL	2.619	183	0.005	0.010	12.531968064528300

One-Sample Effect Sizes

ratingmax_group			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_SPEL	Cohen's d	64.216426342785500	-0.057	-0.166	0.053
		Hedges' correction	64.367425137043600	-0.057	-0.166	0.053
2	diff_NAPLAN_SPEL	Cohen's d	62.183588237195000	-0.170	-0.314	-0.025
		Hedges' correction	62.435740717191900	-0.169	-0.313	-0.025
3	diff_NAPLAN_SPEL	Cohen's d	54.172008238535200	0.180	-0.026	0.386
		Hedges' correction	54.623651171470600	0.179	-0.026	0.383
4	diff_NAPLAN_SPEL	Cohen's d	64.901390679282800	0.193	0.047	0.339
		Hedges' correction	65.168902775368900	0.192	0.047	0.337

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created	25-JUN-2025 14:26:14

Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	ratingmax_group
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=43.486 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_WRIT /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.09
	Elapsed Time	00:00:00.38

One-Sample Statistics

ratingmax_group		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_WRIT	320	37.595030406250000	65.020917397321300	3.634779781495230
2	diff_NAPLAN_WRIT	187	41.699197165775400	66.640164237005300	4.873211444582500

3	diff_NAPLAN_WRIT	92	55.400474130434800	62.51233928583590 0	6.51736189876156 0
4	diff_NAPLAN_WRIT	184	49.385778206521700	60.13881735236890 0	4.43349243563767 0

One-Sample Test

ratingmax_group		Test Value = 43.486 t	df	Significance One-Sided p	Two-Sided p	Mean Difference
1	diff_NAPLAN_WRIT	-1.621	319	0.053	0.106	-5.890969593750020
2	diff_NAPLAN_WRIT	-0.367	186	0.357	0.714	-1.786802834224580
3	diff_NAPLAN_WRIT	1.828	91	0.035	0.071	11.91447413043480 0
4	diff_NAPLAN_WRIT	1.331	183	0.092	0.185	5.899778206521720

One-Sample Effect Sizes

ratingmax_group			Standardizer[a]	Point Estimate	95% Confidence Interval Lower	Upper
1	diff_NAPLAN_WRIT	Cohen's d	65.020917397321300	-0.091	-0.200	0.019
		Hedges' correction	65.174288726224700	-0.090	-0.200	0.019
2	diff_NAPLAN_WRIT	Cohen's d	66.640164237005300	-0.027	-0.170	0.117
		Hedges' correction	66.910387991473600	-0.027	-0.169	0.116
3	diff_NAPLAN_WRIT	Cohen's d	62.512339285835900	0.191	-0.016	0.396
		Hedges' correction	63.033517236917000	0.189	-0.016	0.393
4	diff_NAPLAN_WRIT	Cohen's d	60.138817352368900	0.098	-0.047	0.243

	Hedges' correction	60.386698960415900	0.098	-0.047	0.242

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:28:08
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	SCHOOL_ GROUP
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST /TESTVAL=43.486 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_WRIT /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.05
	Elapsed Time	00:00:00.56

One-Sample Statistics

SCHOOL_GROUP		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_WRIT	256	52.755575312500000	60.684225172490400	3.792764073280650
2	diff_NAPLAN_WRIT	260	48.913323615384600	68.301247606933100	4.235863559518880
3	diff_NAPLAN_WRIT	267	29.172640411985000	61.056371210446400	3.736589236362850

One-Sample Test

SCHOOL_GROUP		Test Value = 43.486				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_WRIT	2.444	255	0.008	0.015	9.269575312500000
2	diff_NAPLAN_WRIT	1.281	259	0.101	0.201	5.427323615384620
3	diff_NAPLAN_WRIT	-3.831	266	0.000	0.000	-14.313359588015000

One-Sample Effect Sizes

SCHOOL_ GROUP			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_WRIT	Cohen's d	60.684225172490400	0.153	0.029	0.276
		Hedges' correction	60.863440298815200	0.152	0.029	0.275
2	diff_NAPLAN_WRIT	Cohen's d	68.301247606933100	0.079	-0.042	0.201
		Hedges' correction	68.499829841108400	0.079	-0.042	0.201
3	diff_NAPLAN_WRIT	Cohen's d	61.056371210446400	-0.234	-0.356	-0.113
		Hedges' correction	61.229199455938500	-0.234	-0.355	-0.112

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:29:38
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	SCHOOL_ GROUP

	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=62.537 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_SPEL /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.09
	Elapsed Time	00:00:00.46

One-Sample Statistics

SCHOOL_GROUP		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_SPEL	256	73.598160678591300	57.705271113417700	3.606579444588610
2	diff_NAPLAN_SPEL	261	62.015793214675400	67.108818384968200	4.153931574886340
3	diff_NAPLAN_SPEL	267	52.649902064024400	63.187199880805100	3.866993833235350

One-Sample Test

SCHOOL_GROUP		Test Value = 62.537				
		t	df	Significance		Mean Difference

				One-Sided p	Two-Sided p	
1	diff_NAPLAN_SPEL	3.067	255	0.001	0.002	11.061160678591300
2	diff_NAPLAN_SPEL	-0.125	260	0.450	0.900	-0.521206785324566
3	diff_NAPLAN_SPEL	-2.557	266	0.006	0.011	-9.887097935975560

One-Sample Effect Sizes

SCHOOL_ GROUP			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_SPEL	Cohen's d	57.705271113417700	0.192	0.068	0.315
		Hedges' correction	57.875688671239400	0.191	0.068	0.314
2	diff_NAPLAN_SPEL	Cohen's d	67.108818384968200	-0.008	-0.129	0.114
		Hedges' correction	67.303180232428700	-0.008	-0.129	0.113
3	diff_NAPLAN_SPEL	Cohen's d	63.187199880805100	-0.156	-0.277	-0.036
		Hedges' correction	63.366059722562100	-0.156	-0.276	-0.036

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created	25-JUN-2025 14:31:33
Comments	

Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	SCHOOL_ GROUP
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=75.058 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_READ /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.08

One-Sample Statistics

SCHOOL_ GROUP		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_READ	259	76.610264227247400	60.638433080295300	3.767888897378250
2	diff_NAPLAN_READ	261	82.683559016457700	64.276716720244500	3.978628882758790

3	diff_NAPLAN_READ	268	65.549931875689500	65.637214306555200	4.009431000463790

One-Sample Test

SCHOOL_GROUP		Test Value = 75.058				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_READ	0.412	258	0.340	0.681	1.552264227247390
2	diff_NAPLAN_READ	1.917	260	0.028	0.056	7.625559016457740
3	diff_NAPLAN_READ	-2.371	267	0.009	0.018	-9.508068124310500

One-Sample Effect Sizes

SCHOOL_GROUP			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_READ	Cohen's d	60.638433080295300	0.026	-0.096	0.147
		Hedges' correction	60.815422205317700	0.026	-0.096	0.147
2	diff_NAPLAN_READ	Cohen's d	64.276716720244500	0.119	-0.003	0.240
		Hedges' correction	64.462876180522500	0.118	-0.003	0.240
3	diff_NAPLAN_READ	Cohen's d	65.637214306555200	-0.145	-0.265	-0.024
		Hedges' correction	65.822310655864700	-0.144	-0.264	-0.024

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:33:44
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	SCHOOL_ GROUP
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.
Syntax		T-TEST /TESTVAL=115.846 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_NMCY /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.21

One-Sample Statistics

SCHOOL_GROUP		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_NMCY	256	120.619426220659000	78.606854103732700	4.912928381483290
2	diff_NAPLAN_NMCY	261	126.810988768765000	75.662678226754200	4.683402206899530
3	diff_NAPLAN_NMCY	268	100.177814622272000	85.331476434387500	5.212449531046140

One-Sample Test

SCHOOL_GROUP		Test Value = 115.846				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_NMCY	0.972	255	0.166	0.332	4.773426220658560
2	diff_NAPLAN_NMCY	2.341	260	0.010	0.020	10.964988768764600
3	diff_NAPLAN_NMCY	-3.006	267	0.001	0.003	-15.668185377727600

One-Sample Effect Sizes

SCHOOL_GROUP			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_NMCY	Cohen's d	78.606854103732700	0.061	-0.062	0.183
		Hedges' correction	78.838999068064900	0.061	-0.062	0.183
2	diff_NAPLAN_NMCY	Cohen's d	75.662678226754200	0.145	0.023	0.267

		Hedges' correction	75.881813927216100	0.145	0.023	0.266
3	diff_NAPLAN_NMCY	Cohen's d	85.331476434387500	-0.184	-0.304	-0.063
		Hedges' correction	85.572110424359000	-0.183	-0.303	-0.063

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

T-Test

Notes

Output Created		25-JUN-2025 14:34:59
Comments		
Input	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	SCHOOL_ GROUP
	N of Rows in Working Data File	807
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST /TESTVAL=88.079 /MISSING=ANALYSIS /VARIABLES=diff_NAPLAN_GP /ES DISPLAY(TRUE) /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.08
	Elapsed Time	00:00:00.33

One-Sample Statistics

SCHOOL_GROUP		N	Mean	Std. Deviation	Std. Error Mean
1	diff_NAPLAN_GP	256	89.516862522912100	74.095185933933400	4.630949120870840
2	diff_NAPLAN_GP	261	95.671308197845900	82.937580424167000	5.133707348150710
3	diff_NAPLAN_GP	267	79.178626080030800	76.302090635032300	4.669612112979030

One-Sample Test

SCHOOL_GROUP		Test Value = 88.079				
		t	df	Significance		Mean Difference
				One-Sided p	Two-Sided p	
1	diff_NAPLAN_GP	0.310	255	0.378	0.756	1.437862522912070
2	diff_NAPLAN_GP	1.479	260	0.070	0.140	7.592308197845940
3	diff_NAPLAN_GP	-1.906	266	0.029	0.058	-8.900373919969230

One-Sample Effect Sizes

SCHOOL_GROUP			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
1	diff_NAPLAN_GP	Cohen's d	74.095185933933400	0.019	-0.103	0.142
		Hedges' correction	74.314006856001100	0.019	-0.103	0.141
2	diff_NAPLAN_GP	Cohen's d	82.937580424167000	0.092	-0.030	0.213
		Hedges' correction	83.177785835960600	0.091	-0.030	0.212
3	diff_NAPLAN_GP	Cohen's d	76.302090635032300	-0.117	-0.237	0.004
		Hedges' correction	76.518073933587300	-0.116	-0.236	0.004

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.