Association Between Playing Chess and Solving Mathematical Tasks

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Sammendrag

Denne masteroppgaven undersøker om det finnes en korrelasjon mellom det å spille sjakk og det å løse matematiske oppgaver. Forskningen er basert på et sammenligningsstudie der to ulike grupper sammenlignes gjennom samme matematikkprøve. Gruppene ble delt inn i en sjakkgruppe, der inkluderingskravet var å ha spilt sjakk aktivt i klubb i minst seks måneder eller mer, samt en kontrollgruppe bestående av en vanlig skoleklasse. Begge gruppene hadde 14 deltakere hver som alle gjennomførte prøven. Gjennom prøven ble det testet en rekke matematiske ferdigheter som mønstergjenkjenning, kunnskap om koordinatsystem, hoderegning, fortegnsregler og kombinatorikk. Prøven tok én time og inneholdt ni oppgaver, hvorav disse kan deles opp i 32 ulike deloppgaver.

Masteroppgaven tar for seg følgende forskningsspørsmål:

- Er det en sammenheng mellom å spille sjakk og å løse matematiske oppgaver?
- Hva forårsaker denne sammenhengen?
- Hvilke overførbare ferdigheter knytter sjakk og matematikk sammen?

Resultatene av prøven ble analysert ved hjelp av ikke-parametriske tester. 31 av 32 oppgaver ble analysert med kji-kvadrat-analyse, mens den gjenværende oppgaven ble analysert med Mann-Whitney U-test. Resultatene på prøven indikerte en statistisk signifikant forskjell på ni av 32 deloppgaver i favør sjakkgruppen. Videre presterte sjakkgruppen best på 31 av 32 deloppgaver, selv om ikke alle viste en statistisk signifikant forskjell. Kontrollgruppen presterte bedre på én av 32 oppgaver, men denne viste ingen statistisk signifikant forskjell.

Resultatene indikerte positive overføringseffekter mellom sjakk og matematikk, spesielt i oppgaver som inneholder en form for mønstergjenkjenning. Andre overførbare ferdigheter som ikke nødvendigvis er spesifikke for sjakkspillet, men heller aktiviteten sjakk, ble også observert som positive bidragsytere. Eksempler på dette er tidsstyring og logisk resonnement.

Abstract

This thesis investigates the association between playing chess and solving mathematical tasks by exploring potential transferable skills between the two domains. The research questions are:

- Is there a relationship between playing chess and solving mathematical tasks?
- What causes this relationship?
- Which transferable abilities connect chess and mathematics?

A comparative study was conducted, collecting data from a chess club and a control group from a regular school. Both groups were given similar tests in order to make it possible to compare their performances. The findings revealed that the chess group performed better overall, suggesting an association between playing chess and solving mathematical tasks. The most significant difference was observed in the task involving pattern recognition, which is identified as a key transferable skill between the two domains.

Other transferable skills, such as time management and logical reasoning, were also indicated. These findings highlight the importance of incorporating diverse activities in educational settings to enhance transferable skills across different domains. The results support the possible inclusion of chess as an activity within the Norwegian school system, as it appears to be related to general mathematical problem-solving abilities.

Preface

As an avid chess player and a mathematics enthusiast, I have always been intrigued by the potential connections between these two fields. Over the years, I have come across various studies and articles that explore the relationship between chess and mathematics, and I have been fascinated by the insights they provide. As I embarked on my master's degree program, I knew that I wanted to delve deeper into this area of study and explore it in greater detail. Thus, I decided to write my master’s thesis on the relationship between chess and solving mathematical tasks.

My motivations for choosing this topic were manifold. Firstly, I was keen to explore the role of mathematical concepts and principles in chess strategy and tactics. I wanted to understand how chess players use mathematical reasoning and analytical skills to make decisions and outmaneuver their opponents. Furthermore, I was interested in the potential benefits of playing chess for improving mathematical abilities. I wanted to investigate whether there was empirical evidence to support the idea that playing chess could help develop important cognitive skills that are useful in mathematical contexts. Finally, I was intrigued by the broader implications of the relationship between chess and mathematics. I wanted to explore how this relationship could be used to enhance learning and teaching in both fields and to promote further use in the Norwegian curriculum.

Overall, my motivations for writing my master’s thesis about the relationship between chess and mathematics were driven by a curiosity to understand the deep connections between these two fascinating fields and to explore the potential implications of these connections for learning, cognition, and interdisciplinary collaboration.

I would like to take this opportunity to express my deepest gratitude to my supervisors for their invaluable guidance, support, and encouragement throughout my master's thesis journey. Their insightful feedback and expert advice have been instrumental in shaping my research and helping me stay on track.

I would also like to extend my thanks to the teachers from the elementary school and the coordinators from the partaking chess clubs for their participation in this study. Their willingness to share their experiences and insights has been invaluable in helping me gain a deeper understanding of the relationship between chess and mathematics.

I am also grateful to all the participants who generously gave their time and energy to take part in this study. Their contributions have been crucial in helping me gather the data needed to conduct my research.

Finally, I would like to thank my family and friends for their unwavering support, encouragement, and understanding throughout this process. Their belief in me and their willingness to cheer me on and give me motivational advice has been a constant source of motivation and inspiration.

To all those who have helped me along the way, I offer my heartfelt thanks. This thesis would not have been possible without your support and encouragement.

Table of contents

Contents

1. Introduction

1.1 Background and purpose of the study

Researchers have long been interested in the connection between chess playing and mathematical abilities. While some studies have indicated a positive link between the two (Scholz et al,. 2008), others have failed to find any significant correlation (Sala et al,. 2016). This investigation seeks to explore the relationship between chess playing and math proficiency among 10–12-year-old children in Norway. Chess has become increasingly popular in Norway over the past decade, thanks in part to the country's world champion player, Magnus Carlsen (Bergh, 2015). Chess has become a common pastime among children across the nation. Some countries, including the United States, France, and Argentina, provide chess as an elective subject, with a few even mandating compulsory classes (Gobet & Campitelli, 2001).

This study seeks to determine whether actively participating in a chess club and playing chess can enhance mathematical task-solving skills in comparison to not participating in such a club. There have been conducted several studies on the correlation between playing chess and solving mathematical tasks. However, there is a lack of studies in Norway. The findings of this study will contribute to the ongoing discussion on the relationship between chess playing and mathematical ability, particularly in the context of Norway, while also supporting more of the findings from an international standpoint. Additionally, the study will be a contribution to the ongoing international research on chess instruction in school.

Furthermore, the results may have practical implications for parents, educators, and policymakers in terms of promoting chess playing as a tool to enhance math skills in children. This study provides evidence that there should be a discussion about supporting chess playing in educational programs aimed at improving mathematical abilities or otherwise show an indication for future research that chess has some interesting transferable abilities to the fields of mathematics.

1.2 Research problems, objectives and aims

The research aims to explore any correlation between the two domains of chess and mathematics. The research has the aim of being an introduction to explore the relationship between playing chess actively and solving mathematical tasks. The results of this study could indicate new and interesting insights into how humans develop cognitive thinking outside of the "classical" mathematical education and could be a newfound way of teaching more complex mathematical principles with different mediating artifacts, such as chess.

The research questions to be answered in this thesis is as following;

- ***Is there a relationship between playing chess and solving mathematical tasks?***
- ***What causes the relationship between playing chess and the ability to solve mathematical tasks?***
- ***Which are the main transferable abilities that connects chess and mathematics?***

These research questions address the key focus on the thesis and addresses the main concern of the thesis which is to explore the relationship, association or correlation between chess and mathematics. Furthermore, the study provides insight into some of the deep questions concerning which of the potential transfers are the most transferable between the two domains.

1.3 Scope and limitations

The scope of this study is primarily constrained by the novelty of the research field, particularly in the context of Norway. As a result, the findings will involve more general speculations about the relationships rather than offering concrete solutions as suggested by existing theories. Nevertheless, there has been a recent increase in studies exploring the correlation between chess and education in general, which provides insights into potential positive or negative associations.

There are some limitations that impacts the study, including a relatively small sample size of 28 participating students. This could lead to less robust statistical outcomes and increased vulnerability to randomness. Despite this, the study's objective is to investigate the relationship between playing chess and solving mathematical tasks, a goal that can still be pursued with a smaller sample size.

Regarding available resources, the research timeframe is limited to six months for both the paper and the research period, preventing a more extensive study. Additionally, the limited number of children actively playing chess in the Agder region led to the inclusion of some participants from Oslo, resulting in minor geographical variance on the results. While this factor is unlikely to significantly impact the study, as all primary school students in Norway follow the same curriculum, it may still introduce minor discrepancies.

1.4 Literature review

The literature review for this study is heavily influenced by the findings of previous research with similar methodology and goal. While these earlier studies provide insight into the probable outcomes of the tests conducted in this research, none have been conducted in Norway. This study offers a fresh perspective on the relationship between chess and mathematics in a Norwegian context while still having applications for the international aspect in terms of chess and mathematics both being an international activity. The primary theoretical framework is derived from prior research on the transfer of skills between different domains, as this aligns with the objectives of the research questions. Furthermore, Detterman (1993) offered valuable information on what to anticipate when exploring transfers between different fields and supplied additional details about the notions in which I will refer to as specific and non-specific transfers. Specific and non-specific transfers refer to transferable skills that can be applied across various domains. Specific transfers involve more direct skills, like the similarity between a chessboard's dimensions and the Cartesian coordinate system found in mathematics. On the other hand, non-specific transfers pertain to more abstract abilities that may not have a direct connection to a particular domain, such as logical reasoning or time management.

These two crucial concepts have been instrumental in designing and shaping the mathematical tasks completed by the participants to generate the research data and provided the framework for what to expect in terms of transfers between chess and mathematics.

Building on Vygotsky's (1978) theories, the theory explores the potential benefits of utilizing chess as a pedagogical artifact to enhance mathematical learning and understanding. By examining previous research, the review seeks to understand the mechanisms through which chess may facilitate the development of problem-solving skills, abstract thinking, and logical reasoning in students. Additionally, the social aspects of chess play are considered in light of Vygotsky's (1978) emphasis on the role of social interaction in learning.

1.5 Thesis structure

The thesis is structured with the following chapters:

- **Introduction** – The introduction provides an overview of the study's background, research challenges, scope, and limitations, along with an overview of the key literature supporting the thesis's claims.

- **Theory** – The theory chapter delves into more specific literature related to chess and its associated learning theory. It particularly focuses on the transferability of chess skills to the field of mathematics.
- **Methods and data** – The methods and data chapter presents details about the experiment and research, including the materials, tests, and ethical considerations employed to derive conclusions for the study. Provided in the methodology chapter is an overview of some of the mathematical tasks used to gather the research data. Furthermore, a full overview is provided in the appendix.
- **Results** – The results chapter compiles and presents information from the non-parametric tests used in the study; This includes Chi square tests and one Mann-Whitney U test.
- **Discussion** – The discussion chapter in the thesis offers interpretations of the statistical test results, along with explanations for their outcomes. It is organized into multiple subchapters that examine the established transfer of skills between chess and mathematics in light of the statistical findings. Additionally, implications for practice and the study's limitations are addressed.
- **Conclusion** – The paper's conclusion serves as the final remarks on the relationship between chess and mathematics. It revisits the research questions and provides a summary of the answers to them.
- **References** – References to the literature used throughout the master thesis.
- **Appendices** – A list of extra documents including the instrument used in the thesis.

2. Theory

2.1 Summary of previous research

The following studies have explored various aspects of mathematics and chess, including the use of mathematical concepts such as game theory, probability theory, and combinatorics in chess strategy and tactics. Researchers have also examined the cognitive processes involved in playing chess, including the role of pattern recognition, spatial reasoning, and problem-solving skills. There has also been studies have explored the potential benefits of playing chess for improving mathematical abilities, particularly in the areas of problem-solving. Furthermore, researchers have suggested that playing chess may help develop important cognitive skills that are useful in mathematical contexts. Hence, the relationship between mathematics and chess is a fascinating area of study that has captured the attention of researchers for decades. Continued research may lead to a deeper understanding of the connections between the two fields and their potential implications for learning and cognition. The relationship between chess and mathematics has been the subject of numerous research papers over the years. The following summary chapter examines various papers that explore the effects of chess instruction on mathematics performance and cognitive skills.

Your move: The effect of chess on mathematics test scores, by Rosholm et al. (2017), examined the impact of chess instruction on mathematics test scores in a randomized controlled trial. The study involved 482 Danish students in grades 1-3, who were randomly assigned to a treatment group that received weekly chess instruction or a control group that did not receive chess instruction. 322 of these had one out of 4 weekly mathematics lectures replaced by chess instruction. The substituted lectures were over a span of the spring semester and the first half of the fall semester. The results showed that the treatment group had significantly higher mathematics test scores than the control group, suggesting that chess instruction may have a positive effect on mathematics performance. In conclusion the findings are consistent with recent research of the impact of chess playing on mathematical abilities. Additionally, the study indicates that chess instruction also demonstrated the potential benefit of effect in terms of happiness and reduced boredom in class, although more research needs to be conducted to confirm or deny these findings (Rosholm et al., 2017).

The Effects of Chess Instruction on Pupils Cognitive and Academic Skills: State of the Art and Theoretical Challenges by Sala et al. (2017), reviewed the literature on the effects of chess instruction on cognitive and academic skills. The authors found that while there is some evidence to suggest that chess instruction may improve cognitive skills such as problem-solving and reasoning, the evidence is not conclusive. Furthermore, the authors noted that the effects of chess instruction on academic skills such as mathematics performance are mixed, with some studies reporting positive effects and others reporting no significant effects (Sala et al., 2017). The importance of this paper is to show the lack of a firm theoretical ground to show why chess instruction could or should enhance mathematical abilities. The example being used is an instance of near and far transfer to the generalization of chess skill between the two domains, however Sala et al. (2017) point out that chess is a cognitively demanding activity. Therefore, chess require domain-general cognitive abilities which suggest that this might be trained with practice in the game, and only then may cognitive abilities transfer to different domains.

Impact of chess training on mathematics performance and concentration ability of children with learning disabilities by Scholz et al, (2008), investigated the impact of chess training on mathematics performance and concentration ability in children with learning disabilities. The study involved German students in grades 3-4 who were randomly assigned to a treatment group that received sessions of chess training or a control group that did not receive chess training. The study duration was one school year and covered one replacement lesson with chess instruction a week for the experimental group. Inclusion criteria from the experimental group was an IQ range between 70 – 85. The results showed that the treatment group had significantly higher mathematics scores and concentration abilities over the span of the study, suggesting that chess training may be beneficial for children with learning disabilities and shows some of the potential non-specific transfers discussed later in the theory chapter (Scholz et al,. 2008).

Does chess instruction enhance mathematical ability in children? A three-group design to control for placebo effects by Sala et al. (2016), used a three-group design to control for placebo effects in a study of the effects of chess instruction on mathematics performance. The study involved 52 Italian students being 10 years old in three classics of primary school, who were randomly assigned to a treatment group that received chess instruction, a placebo group that received non-chess instruction, and a go-group that received 15 hours of lessons in the strategic board game go. The chess and go group replaced one weekly lesson dedicated to mathematics and science. The results of the study showed that chess seem to be a more effective in enhancing children’s mathematical skills than go, but not than regular school activities. The result of this study is interesting because of the conflicting results in comparison with previous research. This means that studies involving comparative research strategies often is volatile to randomness, this is something to take into consideration moving forward with this thesis.

Can chess training improve PISA scores in mathematics? by Trinchero (2013), examined the effects of chess training on PISA scores in mathematics. The study involved 568 Italian students, aged 8-10, who were assigned to four different groups being: Experimental (G1), Experimental without pretests (G2), Control (G3), and Control without pretests (G4). The study design was conducted over the span of one school year. Where G1 and G2 received chess lessons in school hours. The study used a pre-test and post-test method to gain statistics for before and after. The results showed that the experimental group had significantly higher PISA scores in mathematics than the control group after the conducted pre and post-tests. suggesting that chess training may have a positive effect on mathematics performance at international level.

Educational benefits of chess instruction: A critical review by Gobet & Campitelli (2006), provided a critical review of the literature on the educational benefits of chess instruction. The authors found that while there is some evidence to suggest that chess instruction may improve cognitive skills such as problem-solving and reasoning, the evidence on the effects of chess instruction on academic skills such as mathematics performance is mixed. Furthermore, the authors noted that the studies that do report positive effects are often limited by small sample sizes, lack of randomization, and other methodological issues. Overall, while the evidence on the relationship between chess and mathematics is not conclusive, the studies reviewed in this summary suggest that there may be a positive effect of chess instruction on mathematics performance and cognitive skills, particularly for children with learning disabilities.

Further research is needed to better understand the mechanisms underlying this relationship and to identify the most effective ways to integrate chess instruction into educational programs (Gobet & Campitelli, 2006). The study by Gobet and Campitelli (2006) is a crucial review on the theoretical framework for the claims of chess as an educational topic. However, the study points out that claims of such a transfer is not unheard of and has in fact been a subject of interested over decades since the transfer ability on Latin to other subjects such as medicine and sciences.

In general, these papers indicate that there is some conflicting evidence regarding the impact of chess instruction in schools on mathematical test scores. However, the majority of studies in this area have demonstrated an improvement in scores over an extended period of time with the implementation of chess instruction. Overall, previous research shows interesting findings towards replacements on chess and mathematics. Most of the studies shows indication towards a positive outcome, where being exposed to chess education promotes and enhances mathematical abilities.

As for future focus on this thesis, one of the topics will be dedicated to exploring more of Trinchero (2013) suggestion: that further research should focus more on which abilities are the main topic of interest in transfer between chess and mathematical abilities. PISA are standardized tests that explore a broad range of mathematical skills. However, it is noteworthy that a PISA test is best to imply non-specific transfer abilities as they test a larger range of different mathematical abilities. In order to view the more specific transfers, a research test to apply fewer but more specific transfer abilities between the two domains could prove a useful addition to the field.

2.2 Chess as mediated artifact

Vygotsky (1978) had the perspective that pedagogical artifacts play a great role in how humans learn and perceive mathematics, and Mariotti (2009) claims that "Following the seminal idea of Vygotsky, and elaborating on it, we postulate that an artifact can be exploited by the teacher as a tool of semiotic mediation to develop genuine mathematical signs, that are detached from the use of the artifact, but nevertheless maintain with it a deep semiotic link". Mariotti's (2009) statement makes it clear that it is possible to use artifacts in education to future develop mathematical concepts while they are detached from the use of the artifact. Meaning that teaching transfers deeper than the artifact itself.

Vygotsky employed the concept of a tool to elucidate the manner in which we acquire culture and knowledge, as well as the process of socializing with others. Language, particularly oral language, serves as the most crucial tool in this context (Vygotsky, 1978). Furthermore, the theory suggests allowing children use language to stimuli their egocentric speech. This will allow a foundation of logical and abstract thinking (Vygotsky, 1978).

One can view chess as a similar tool on how Vygotsky explain language as a mediating artifact:

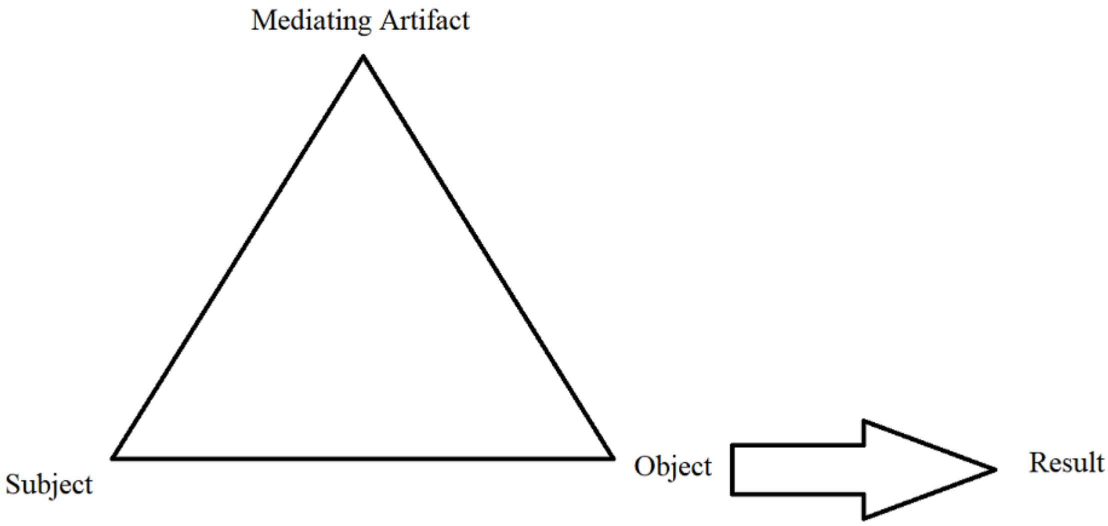

Figure 1: Mediating artifact (adapted from Vygotsky, 1978)

In this framework, the student serves as the subject, with chess acting as a mediating artifact, while mathematics representing the target concept. These elements collaborate to yield an outcome. Importantly, the intermediary tool can be replaced with any instrument, mode of communication, or human interaction. In the context of this research, the enhancement of mathematical skills is the intended outcome or objective. It is, however, important to note that Vygotsky's framework simply suggests that various outcomes can be achieved when a mediating artifact bridges the gap between a subject and an object, without necessarily guaranteeing a positive impact.

Building upon Vygotsky's (1978) theories, this study aims to investigate the relationship between the subject (Student), mediating artifact (Chess), and object (Mathematics), in terms of a positive result. In this sense, chess can be considered an exemplary pedagogical artifact that fosters mathematical and logical thinking. As a strategic board game, chess requires players to anticipate and calculate various potential moves and consequences, engaging their problem-solving and critical thinking skills. Similar to the way language operates as a tool for thought and communication, chess serves as a semiotic mediator, allowing learners to engage with abstract concepts and deepen their cognitive processes.

In the context of mathematics education, chess can be used as a teaching tool that not only develops logical reasoning but also stimulates a learner's ability to visualize patterns, analyze situations, and make decisions. By employing chess as a pedagogical artifact, educators can create a dynamic learning environment that encourages students to actively engage with mathematical concepts and develop a deeper understanding. Furthermore, the social aspect of playing chess is in line with Vygotsky's (1978) emphasis on the importance of social interaction in the process of learning. When students collaborate or compete with others, they actively share and negotiate strategies, evaluate their decisions, and adapt their thinking based on the feedback they receive. This social engagement fosters a collaborative learning environment, enhancing the overall educational experience (Vygotsky, 1978).

All in all, it is my belief that chess can be considered a powerful pedagogical artifact that aligns with Vygotsky's (1978) theories, serving as a semiotic mediator and a means of fostering social interaction. By incorporating chess into mathematics education, educators can create engaging and dynamic learning experiences that enhance students' abilities to think critically, reason logically, and ultimately develop a deeper understanding of mathematical concepts.

To achieve a more profound comprehension of mathematical concepts, it is essential to examine the processes and various domains from which we can derive learning. In a typical mathematics classroom, the teacher strives to foster understanding among students by presenting examples from the field of mathematics and assigning tasks that align with the strategies demonstrated, for instance, on the blackboard. Although this method effectively transfers knowledge directly related to mathematics, it is crucial to recognize that transferable skills from other domains can also be successfully applied to the study of mathematics. By incorporating these skills, learners may gain additional perspectives and enhance their overall understanding of mathematical concepts. One alternative approach to traditional blackboard education could be to investigate chess or other activities as means for transferring knowledge.

2.3 Transfer ability

The term "transfer" refers to the ability to apply learning and skills across different domains. There are two types of transfer abilities: "specific" and "non-specific."

Specific transfer refers to the concrete content and relationships between two fields. For example, a cashier who works with mental arithmetic expediting customers can transfer their skills to basic arithmetic in the field of mathematics, they would most likely be more confident and quicker than people not working with mental calculations on a daily basis. In terms of a chess player, an example of a specific transfer could be the understanding of two-dimensional coordinate systems (relating to the playing board). Other examples of potential specific transfers between chess and mathematics related to combinatorics, probability theory, game theory, algorithms, optimization, decision trees, graph theory which all will be exemplified and explored throughout this thesis.

A non-specific transfer, on the other hand, involves general concepts that two fields share. For instance, a musician works with underlying fractions while writing notes for a song. This demonstrates non-specific transfer, as they are applying principles of mathematics to their work, while not directly applying known patterns of rules (Detterman, 1993). In the field of chess, it is more common that non-specific transfer related to the field of mathematics occur apart from specific transfers. This is due to the nature of transfer not being directly related between each other in most cases apart from coordinate systems and some other more specific transfers.

A chess player's brain must calculate numerous potential moves in various positions to achieve accurate and optimal play. One common non-specific transfer skill in chess is pattern recognition (Holding, 2021), which is also useful for solving numerical sequences or triangular numbers in mathematics. This suggests a non-specific transfer between the two domains, indicating their interconnectedness. Broad knowledge about pattern recognition in chess helps with accuracy and speed directly showing the potential for non-specific transfer when recognizing which strategy to use where in mathematics.

Other non-specific transfers between the domains of chess and mathematics potentially involve; logical reasoning, problem-solving, spatial reasoning, memory, attention to detail, time management, which all will be exemplified and explored throughout this thesis.

Detterman (1993) argues that transfer is not a significant phenomenon in cognitive psychology. He suggests that transfer is not a fundamental process of the human mind, but rather an "epiphenomenon," or a byproduct of other cognitive processes. Furthermore, Detterman (1993) claims that transfer is often studied as a phenomenon, but it is more accurately understood as a reflection of the underlying cognitive processes that produce it.

Transfer is the ability to apply knowledge and skills acquired in one context to new and different situations. For example, a person who learns to play chess may be able to transfer their strategic thinking skills to other areas of life, such as problem-solving in business or politics. Research on transfer has focused on identifying the factors that facilitate or hinder transfer. One key factor is the similarity between the original and transfer tasks. When the tasks are similar, transfer is more likely to occur. However, if the tasks are too dissimilar, transfer may not occur, or it may even result in interference or negative transfer (Detterman, 1993). With this in mind, the level of similarities between chess and mathematics has to be close if a transfer is to carry over in problem-solving mathematical tasks. This could indicate that not all mathematical tasks would be beneficial to the chess player even if it covers logical reasoning or pattern-recognition or otherwise potential transfers.

Another important factor in transfer is the level of abstraction of the knowledge or skills being transferred. Knowledge that is too specific or context-bound may not transfer well to new situations. In contrast, more abstract knowledge or skills may be more adaptable to different contexts (Detterman, 1993).

The study by Karbach and Kray (2009), investigated the effectiveness of executive control training in producing transfer effects in task-switching abilities. Karbach and Kray (2009) tested younger and older adults to examine whether executive control training could improve task-switching performance and whether any training-related benefits would transfer to non-trained tasks. The results of the study showed that task-switching training improved performance on the trained task for both younger and older adults. However, transfer effects were only observed for the younger adults, with improved performance observed on a non-trained task that required the same cognitive processes as the trained task. The older adults, on the other hand, did not show transfer effects (Karbach and Kray, 2009). These findings suggest that the effectiveness of executive control training may depend on age-related differences in cognitive processes. Older adults may have more difficulty transferring cognitive skills to new situations, whereas younger adults (or children) may be more able to generalize their training to other cognitive tasks. The study highlights the importance of considering individual differences in transfer effects when designing training programs. Training programs may need to be tailored to specific age groups or other demographic factors in order to maximize their effectiveness. In general, transfer effects are a crucial aspect of learning and skill acquisition. The ability to transfer knowledge and skills from one context to another is an important indicator of cognitive flexibility and adaptability. Understanding the factors that influence transfer effects can help improve instructional design and facilitate the transfer of learning across different domains (Karbach and Kray 2009). In short working with transferable knowledge seem to effect young children the best, much like how learning works on young children’s mind in general. This points out why working with transferable knowledge is highly useful in elementary school as children’s minds are more adaptable to new inputs from other areas and are more skilled at applying the non-specific and specific transfers to other fields, which is a skill useful to bring onwards to work life in general.

A set of skill acquired in a specific domain can be generalized into other domains such as mathematics, language or more non-spesific general abilities such as memory, time-management or logical reasoning (Gobet & Campitelli, 2006). However, transfer is often limited moving from one task to another. Thorndike (in Gobet & Campitelli, 2006) suggest in his “identical element theory” from 1901, that transfer from one domain to another is possible with the overlap between components from both skills. For chess this would indicate that transfer is possible, but only in very specific parts of the game. Examples of such transfers doesn’t exist in theory. However, one can speculate that pattern-recognition, coordinate systems, time-management, logical reasoning are some of the few transferable abilities that may come to light between the domains of chess and mathematics.

The nature of transfer is disagreed upon within a variety of literature. However, recent research has clearly indicated that a higher level within a domain limits transfer to other domains. Thus, a broader knowledge about many fields transfers better into one field, than a narrow perspective from one field moving onwards to several fields (Gobet & Campitelli, 2006). Examples of this being more understandable is to view chess on the highest level. A chess grandmaster would for instance not automatically prove better in the field of mathematics on average than a 1500-rated FIDE player, because a high level in a specific domain could tend to limit the transfer into other fields. The time used to develop a skill at such a high level acquire specific domain-only knowledge which does not necessarily transfer well over to other fields. (Gobet & Campitelli, 2006).

2.4 Pattern recognition in Chess

According to Holding (2021), chess mastery stems from knowledge of thousands of patterns. Recognition of these patterns will trigger memories associated with plausible moves, which furthermore will be selected by the player. Holding (2021) calls this the recognition-association theory and claims that chess skill is mostly based on memory. Stronger chess players are better than weaker players in short-term memory. Furthermore, in relation to past calculations of lines made on the chessboard, strong chess players benefit from having a strong short-term memory (Holding, 2021). The recognition-association theory is a cognitive psychology theory that explains chess mastery as a result of a player's knowledge of thousands of chess patterns. The theory suggests that recognizing one of these patterns during play triggers the memory of an associated plausible move, which can then be selected or investigated by the player. This theory is widely accepted in cognitive psychology because it seems to integrate several different features of skilled performance.

The theory is based on the observation that stronger chess players are better than weaker players in short-term memory for briefly exposed chess positions. This finding suggests that chess skill depends on memory. However, the theory's support is derived from supplementary findings and assumptions, including the observation that the difference in short-term memory between stronger and weaker players disappears when the test positions are random assortments of pieces (Holding, 2021).

Task-switching abilities may be related to transfer between two domains, but the extent of the relationship depends on the specific tasks and domains involved. For example, if an individual has developed strong task-switching abilities in one domain (such as switching between different programming languages), they may be able to transfer some of those skills to another domain (such as switching between different types of data analysis software). However, the degree of transfer may be limited if the two domains require vastly different types of cognitive processing or if the individual has not had sufficient experience with task-switching in the new domain. Therefore, while task-switching abilities may be a useful cognitive skill in many domains, the extent of transfer between different domains may vary depending on the specific context.

The most influential arguments for the recognition-association theory come from the detailed analyses of memory data made by Chase and Simon (1973). The players reconstruct the positions that were briefly shown by replacing the pieces in groups of two or three at a time, separated by pauses. A master seems to use more of these chunks, or subpatterns, and to possess larger chunks, than a class ll player or a beginner. The acquisition of the long-term chunk-content information would obviously be a matter of experience.

All in all, the recognition-association theory posits that chess mastery results from a player's knowledge of thousands of chess patterns and recognizing one of these patterns during play triggers the memory of an associated plausible move, which can then be selected or investigated by the player (Holding, 2021). Thus, showing that pattern recognition is an important tool for the chess player to eliminate unplausible moves and only consider the plausible, saving both time and computing effort.

In general, previous research and empirical evidence suggest that practice, is more valuable than talent in high levels of performance in chess. Expertise in chess surrounds gathering a vast number of chess-specific patterns that may include appropriate moves, evaluation of the position or plans moving onwards with the game (Gobet & Campitelli, 2006). One way to improve such understandings is to work with someone who already knows these patterns and learn from them. Another way to achieve a high level of play, as empirical evidence suggests that practice is more important than talent, involves analyzing master-level games and understanding how certain positions are played out. Chess at a master level is often perceived as mysterious and awe-inspiring, particularly for lower-level players, but a closer examination of master-level games reveals that most remarkable moves result from rigorous calculation and extensive knowledge about endgames and positional play. Gobet and Campitelli (2006) propose that expert chess performance necessitates domain-specific knowledge of approximately 100,000 perceptual patterns. Their findings indicate that pattern recognition and memory are crucial factors for success in chess, which are also essential skills in mathematics.

2.5 Specific and non-specific transfer in the game of Chess

There are several specific and non-specific transfers between chess and mathematics, as suggested by Sala et al. (2017). However, no study shows the specific or non-specific transfers between chess and mathematics in greater detail. Moreover, Gobet & Campitelli (2006) suggests that pattern recognition and memory serve a great deal when playing chess at a high level. The sub-chapters below attempt to reason on what these specific and non-specific transfers could be in terms of previous research, as well as personal experience working with chess over the span of the last 20 years. These can only be speculative but could prove interesting in terms of the discussion chapter of the findings in the study.

2.5.1 Specific Transfers

One specific transfer between chess and mathematics is the use of coordinate systems. Chess boards are divided into 64 squares, which can be represented using a coordinate system with eight columns (a-h) and eight rows (1-8). This allows players to communicate and record moves in a precise and standardized manner. This coordinate system is similar to the Cartesian coordinate system used in mathematics, which involves a grid with x and y axes to plot points and graph functions.

Another specific transfer is the use of combinatorics and probability theory. Chess involves a finite number of possible positions and moves, and players must calculate and evaluate the possible outcomes of each move. This requires an understanding of combinatorics, which involves counting and analyzing the number of possible outcomes in a given scenario. Probability theory is also relevant to chess, as players must assess the likelihood of certain moves and outcomes based on the position of the pieces.

- **Coordinate Systems**: The use of a standard coordinate system to communicate and record moves on the chessboard, which is similar to the Cartesian coordinate system used in mathematics.
- **Combinatorics**: The application of combinatorics to chess involves analyzing the number of possible outcomes in a given scenario, which is essential for evaluating the strength of different moves.
- **Probability Theory**: Probability theory is also relevant to chess, as players must assess the likelihood of certain moves and outcomes based on the position of the pieces.
- **Game Theory**: Game theory can be used to analyze the strategic decisions made by players in a game of chess, and to model the interactions between players.
- **Algorithms**: Chess-playing algorithms use mathematical techniques, such as search algorithms, to analyze the position of the pieces and select the best move.
- **Optimization**: Chess can be viewed as an optimization problem, where the goal is to find the best move that maximizes the chances of winning the game.
- **Decision Trees**: Decision trees can be used to model the decision-making process in chess, and to evaluate the potential outcomes of different moves.
- **Graph Theory**: Graph theory can be used to model the movement of pieces on the chessboard, and to analyze the relationships between different positions.

These specific transfers demonstrate the potential close relationship between chess and mathematics, and how mathematical concepts can be applied to analyze and improve performance in the game of chess and from chess to mathematics. Although some are more important and clear to envision than others, they reflect the correlation between the domains.

2.5.2 Non-Specific Transfers

One non-specific transfer between chess and mathematics is about the development of logical reasoning and problem-solving skills. In chess, players must analyze the position of the pieces on the board, consider various possible moves, and anticipate the opponent's responses. This requires logical reasoning and problem-solving skills, which are also essential in mathematics. Both chess and mathematics involve breaking down complex problems into smaller, manageable parts and using logic and reasoning to find solutions.

Another non-specific transfer is the development of spatial reasoning skills. Chess players must be able to visualize the position of the pieces on the board and anticipate how they will move in response to different moves. This requires strong spatial reasoning skills, which are also important in mathematics. Many mathematical concepts, such as geometry and trigonometry, involve spatial reasoning and visualization. In conclusion, chess and mathematics have several specific and non-specific transfers that can benefit players in both fields. By playing and studying chess, individuals can develop a range of intellectual skills, including logical reasoning, problem-solving, and spatial reasoning, which are essential in mathematics and other academic disciplines.

The following is a list of some of the potential non-specific transfers:

- **Logical Reasoning**: Both chess and mathematics require strong logical reasoning skills, as players must be able to analyze complex problems, break them down into smaller parts, and apply logical rules and strategies to find solutions.
- **Problem-Solving**: Chess and mathematics both involve solving problems, whether it's finding the best move in a game of chess or solving a complex mathematical equation. Players must be able to think creatively, use trial and error, and evaluate different options to find the best solution.
- **Spatial Reasoning**: Chess and mathematics both require strong spatial reasoning skills, as players must be able to visualize the position of the pieces on the board and anticipate how they will move in response to different moves. Many mathematical concepts, such as geometry and trigonometry, also involve spatial reasoning and visualization.
- **Memory**: Holding (2021) claims that chess mastery stems from strong memory. Chess and mathematics both require a strong memory, as players must be able to remember past moves, patterns, and strategies in order to make informed decisions. This is also a key factor as a chess player when learning previous knowledge that humans have acquired, especially considering opening theory in the game.

- **Attention to Detail**: Both chess and mathematics require a high level of attention to detail, as players must be able to analyze complex information, identify patterns, and make accurate calculations.
- **Time Management**: In chess, players must be able to manage their time effectively, as they only have a limited amount of time to make each move. Similarly, in mathematics, students must be able to manage their time effectively in order to complete assignments and exams within a given time frame.

These non-specific transfers demonstrate the broad range of intellectual skills that can be developed through playing and studying chess, and how these skills can be applied to other academic disciplines, including mathematics. In this study I will investigate whether there is evidence of specific transfer between playing chess and solving mathematical tasks by asking chess players and non-chess players to solve mathematical tasks that tap into potential areas of transfer between the two domains. I will also look into the potential of non-specific transfer by inference on the performance of chess and non-chess players on these same tasks, even though the design of the study will not allow me to make direct observation which relates to non-specific transfer.

3. Methods and data

3.1 Research Design

The research design can be classified as a quasi-experimental. In this research design, the researcher manipulates the independent variable (chess playing) by selecting participants who either do or do not play chess, and then compares their performance on a dependent variable (math skills). The study lacks full control over extraneous variables, as the groups are not randomly assigned and may differ in other ways besides chess playing that could affect math skills. However, by using a control group and by measuring demographic variables such as age and geographical placements, the researcher attempts to minimize these extraneous variables and draw causal inferences about the relationship between chess playing and math skills (Thomas, 2020). A Quasi-experimental research design is often used to test treatments of medicine. However, it is a fitting design to control the effects of playing chess in correlation to mathematics as it has a comparative form and goes well with the paradigm of positivism. This study does not use a treatment-group design as many of the previous research does, but uses a comparative group to a group that has already received a “treatment” (by playing chess for 6 month or more as an inclusion criteria, See 3.3 Participants).

Furthermore, the groups are assigned in such a manner that tries to avoid implementation of randomness such as similar age and geographical placements as far as this was possible in the study (See 3.3 Participants).

The Paradigm of this study is considered as positivism. This is due to the nature of the view of observable realities within the groups, together with the usage of statistics to examine the relationship of chess and mathematics, I as a scientist draw conclusions based on the statistics and does not take height of subjective observation to the extent that this is possible. The epistemology focuses on discovery of facts and further discovery of the plausible relationships between chess and mathematics (Alharahsheh & Pius, 2020).

The comparative research strategy employed in this study is both inductive and deductive in nature. The inductive approach involves observing patterns and relationships between the chess playing and math skills among the participants, while the deductive approach tests the hypothesis that chess playing influences math skills. This combination of inductive and deductive reasoning allows for a comprehensive analysis of the relationship between the two variables, both in terms of statistical significance and practical implications. An example of this refers to the deductive nature that already exist through previous research and that finding results contradicting these would be interesting in the analysis and is what is expected to be found. If the data disagrees with general findings of previous research (See Theory 2.1), the deductive approach would be implemented as a contribution to the general hypothesis that chess enhance mathematical abilities. Moreover, the inductive approach relates to the general conclusions from the statistics gathered and further draws conclusion based on the data set from this study. The conclusions from the analysis would then be implemented as findings from this very case and an addition to the general findings from the deductive approach.

This study can be considered quantitative because it primarily focuses on collecting and analyzing numerical data to investigate the relationship between chess playing and solving mathematical tasks. The research design utilizes a quasi-experimental design and employs statistical tests, such as the Chi-Squared test and the Mann-Whitney U test, to determine the significance of observed differences between the two groups. By measuring the mathematical performance of chess players and non-chess players and using statistical analysis to compare the groups, the study aims to identify potential causal relationships and draw conclusions based on empirical evidence.

3.2 Data Collection

The target population and sample were taken from children going from 5th to 7th grade (Age 10-12) in Norway, this was considered to be the most optimal age group in this particular study due to children in these ages have had more time to develop their chess experience as in Norway it is common to first start playing and exploring chess at the age of 6. The data sources gathered throughout the masters was a primary source of a mathematical test to map the children's mathematical abilities, while the secondary source was a questionnaire to map children's chess experience as well as chess motivations, however the questionnaire was not used for any data-analysis apart from splitting the participants into their respectful group. The mathematical test and the questionnaire were piloted and tested for mistaken, errors, and potential questions. Furthermore, it was later revised to fix some of the potential misunderstandings and errors pointed out by the participants under the pilot test.

3.3 Participants

The study consisted of two groups: the main group, consisting of 14 children aged 10-12, of which 8 were from a chess club in the Oslo region while 6 were from the chess club in the Agder region.

The control group was consisting of 14 children in 6th grade from a school in the Kristiansand area. Participants were recruited through emails with the representative from the chess club and were chosen randomly by the coordinators at the chess club to attend the mathematical test. The majority of the children involved from the chess group was aged 11, apart from two aged twelve 12 and two participants aged 10. The email was extended out to all children participating in the club of that age range, but a low number of children were interested or allowed to participate, thus the main group only consisted of 14 children in total over two chess clubs. Around 80 children were asked to partake on the main group and about 17,5% replied and agreed to take the test.

Inclusion criteria for the main group were being a member of a chess club and being between the ages of 10-12. To participate in the study, individuals must have played in a chess club for at least six months to attend the main group. The inclusion criteria for the control group were being a 6th-grade student at the selected school and being willing to participate in the study. There were no set exclusion criteria for any of the groups. However only half of the control group 14/28 had their NSD forms signed by the test date indicating that only children motivated or allowed by their respected guardians partook in the study, however this made it possible to have an even number of participants.

The main group's age range differs from the control group with the main group being children aged 10-12 (meaning they attend elementary school from 5th- to 7th grade). The control group was strictly set to 6th grade, this was a decision made due to practical reasons as the mathematical test could be performed in a classroom with the attending students participating in that exact class. The broader age range made it possible to have two groups of similar size while keeping the study within a similar age range.

The main group is mostly consisting of boys with the inclusion of one girl. This is a result of chess being a known "boys" activity and thus was problematic to get an equal number of boys and girls partaking. In the control group, the groups are mixed with both boys and girls. The main group had participants from both Oslo (8 participants) and Agder (6 participants), while the control group were a normal school class in the Agder area (14 participants).

3.4 Materials

The test assessed math skills with 9 questions split into two parts, Part 1 and Part 2. The questions were further split into 32 sub-tasks. It covered various mathematical topics such as arithmetic, geometry, mental arithmetic, figure-reasoning, general procedural use and pattern-recognition. Some questions were taken from standardized tests used in the Norwegian school system, including National tests, while others were created to reflect the cognitive processes involved in chess playing. The test was administered on paper, with a 60-minute time limit. Three tasks in part 2 allowed calculator use, where all tasks required "show your work" to receive full credit. Part 1 had six tasks, with some multiple-choice questions and some requiring the "show your work" approach. The tasks were constructed with theory in mind to involve transferable abilities between mathematics and chess.

3.5 Procedure

The study was conducted in a quiet room at the chess clubs and the selected school respectively. Participants in both groups were tested individually. Before the test, participants were given instructions on how to complete the test and how to mark their answers on the answer sheet. They were also informed that the purpose of the study was to compare the mathematical performance of chess players and non-chess players. The children were allowed to ask questions about any misunderstandings that arose from the tasks, however I only answered questions that involved the framework of the test and dismissed any attempt from the children to gain additional mathematical help on the tasks.

I also reminded all the children that it was allowed to use calculator when they started on part 2 of the test. Furthermore, I gave warnings to all participants when there was 30-, 10- and 1-minute left of the test-time.

Before completing the test, participants were asked to fill out a brief questionnaire that asked about their age, gender, and chess experience or their general attitude toward chess. The questionnaire also covered their previous chess experience and FIDE or online chess rating. The questionnaire was mainly used to gather information about which participant to put in which group in regard to the inclusion criteria.

3.6 Data Analysis

To analyze the data from the study, I used non-parametric test such as the Chi-Squared test and the Mann-Whitney U test. The Mann-Whitney U test is a non-parametric statistical test used to determine whether there is a significant difference between the distributions of two independent groups. It is an alternative to the independent samples t-test when the assumptions of normality and equal variances are not met. The Mann- Whitney U test was used to analyze one out of nine tasks. The remaining tasks was analyzed using the Chi-squared test. The Chi-squared test is a statistical test used to determine whether there is a significant association between categorical variables in a sample. It is a non-parametric test often used in hypothesis testing and for contingency table analysis. The most common application of the Chi-squared test is for testing the independence of two categorical variables in a contingency table (also known as a cross-tabulation). This table displays the frequency distribution of the variables across different categories, with each cell representing the observed frequency count for a particular combination of categories. The usage of non-parametric tests was an option to having interviews and a more interpretivist approach to the study.

Without the inclusion of non-parametrical test, the study would likely be a qualitative study with interviews about the different tasks where the children explained their thought process behind the tasks. This would be an interesting study but a different study that would explore the differences in thought process and not strictly performance.

3.7 Ethical Considerations

The study was approved by the Norwegian Centre for Research Data (NSD) and the Institutional Review Board of the University of Agder. Informed consent was obtained from all the participants parents or legal guardians (for participants under 16 years old). Participants were assured that their participation was voluntary and that their responses would be kept confidential. They were also informed that they could withdraw from the study at any time without consequences. No incentives were offered for participation in the study. All the gathered data was secured in a locked drawer in my household.

3.8 Instrument

Included in the appendices are all the tasks that the participants attempted to solve during the study. The test consists of 9 individual tasks which can be further broken down into 32 sub-tasks in total. Each sub-task in the appendices is labeled with a unique number, allowing for easy reference in the subsequent results and discussion sections. As demonstrated in the subchapter below, the sub-task numbers are highlighted in a large red box. This numbering system facilitates cross-referencing between the main text and the appendices in later chapters, making it convenient to navigate back and forth as needed. Throughout this chapter I will present some of the tasks used to give a feeling of understanding of why these tasks were selected/designed.

Specific transfers involve the direct application of mathematical concepts to the game of chess, while non-specific transfers refer to the general intellectual skills and processes that can be developed through playing and studying chess. Most of the previous research tested standardized tests to check for improvements in mathematics with chess instruction. An example of a standardized test could be PISA tests or national tests. Therefore, I decided to tailor the tasks in this thesis to possibly benefit a chess player in terms of transfers. According to research, transfer learning is only observed when there are shared conceptual or perceptual features between the domains involved (Sala et al., 2015). Thus, a standardized mathematical test would only test specific transfers between the two domains and not non-specific problem-solving aspects. It was then important to mix the tasks to have both standardized, problem-solving, pattern recognition, and figure-reasoning tasks. Also included in the test were two tasks about coordination systems and general knowledge about graphs which is a clear transfer between chess and mathematics is the dimensional outlay of the board with clear similarities to a coordinate system. When constructing the tasks for the research group, I included tasks that I think test either a specific or a non-specific transfer, this means in general that a chess player should have a slight advantage in solving these tasks over someone who is not playing chess; if the transfers directly affect mathematical abilities in this test.

3.8.1 Test - Part 1

Abel's puzzles were the first task in the test and had the main objective to view the participants figure-reasoning abilities.

Oppgave 1 – Abel's puzzles

TASK 1

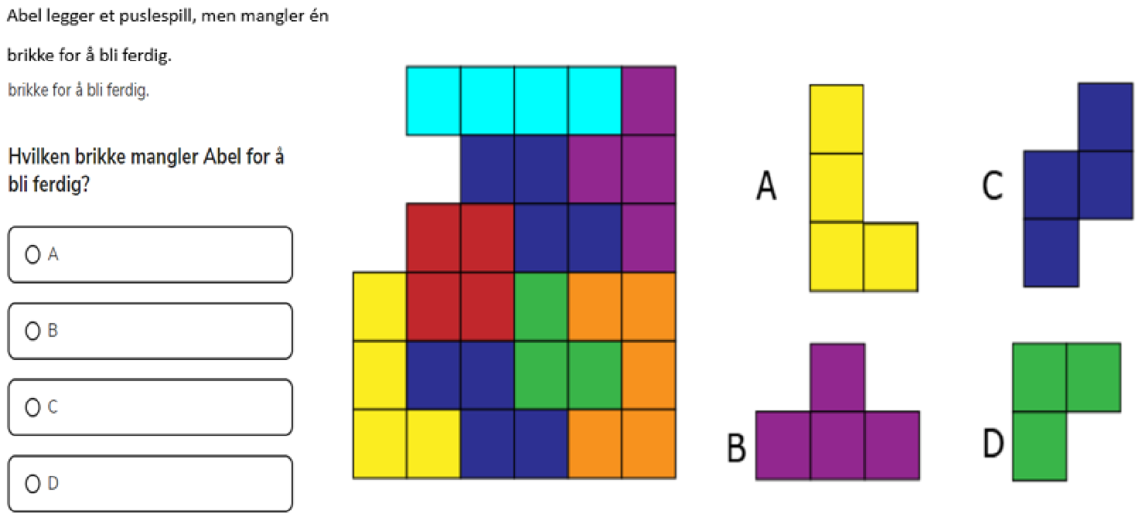

Figure 2: Abel's puzzels (Utdanningsdirektoratet, 2022)

The purpose of the task was to serve as a warm-up exercise for the participants and to establish a baseline for complexity levels. As the test progressed, most tasks increased in complexity. This particular task utilized a multiple-choice format, although not all tasks followed this approach. Abel's puzzles consist of a single sub-task, with each sub-task marked by a red box. This allows for easy reference when discussing the task in the results and discussion chapters and provides readers with the option to examine the tasks themselves if desired (see Appendix).

TASK 2

Oppgave 2 – Treasure hunt

Espen har laget et skattekart. Han har bestemt at skatten skal graves ned i rute E5.

Sett kryss I ruten hvor skatten skal graves ned.

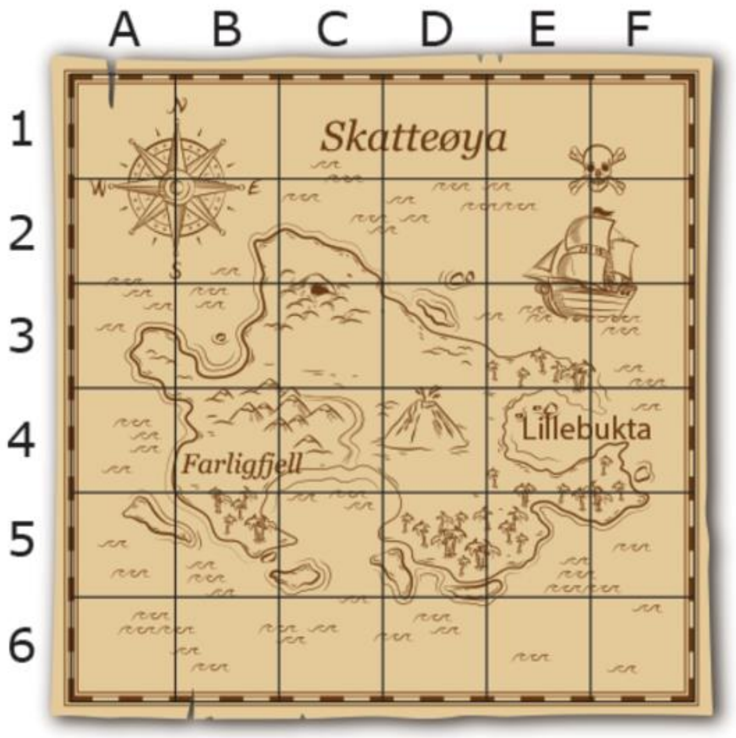

Figure 3: Treasure hunt (Utdanningsdirektoratet, 2022)

The treasure hunt task, which was the second task in the test, aimed to assess participants' understanding of coordinate systems. Given the simplicity of this task, an additional coordinate system task was incorporated into part 2, hypothesizing that all participants would be capable of solving “treasure hunt”.

Figure 4: Road choices

Task 5a- Road choices (See Figure 4) tested the combinatorial understanding of the children and was included as a task to test this aspect. The participants had the option of solving this the way they wanted to, (counting or otherwise provide a calculation with multiplication).

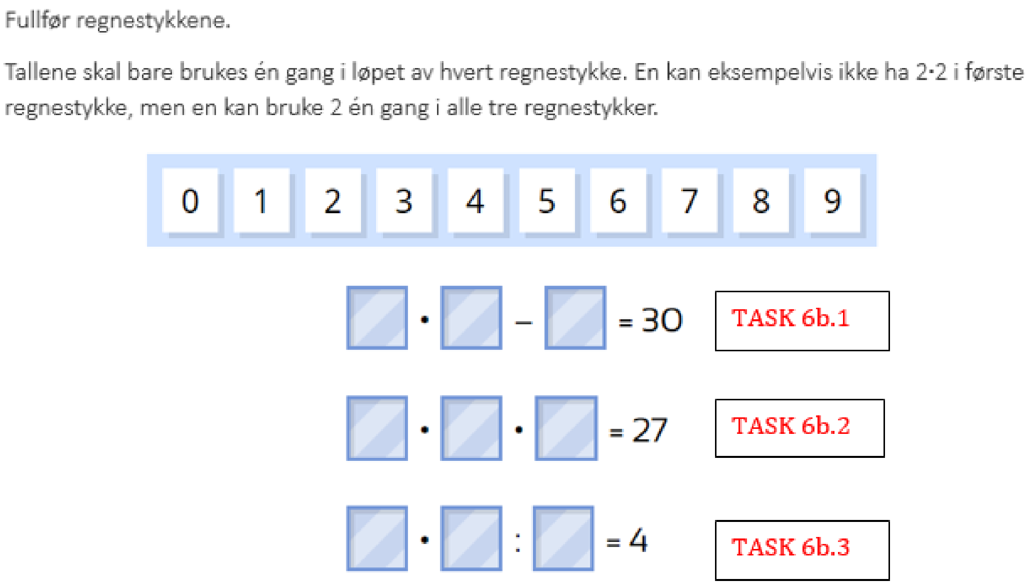

Figure 5: Complete the equations

Task 6 called fill in the squares (See Figure 5) was a task to test children's mental calculation as well as creativity to use different numbers to get different sums. The children were only allowed to use one of each digit per line.

3.8.2 Test - Part 2

--------Del 2---------

Oppgave 1 – Desimallabyrint

TASK 1

Beveg deg ned eller sidelengs (aldri opp) gjennom labyrinten fra start til slutt.

Tegn gjerne inn streker for å vise hvilken vei du har gått. Du skal utføre regneoperasjonene og skrive svarene du kommer til underveis i feltene langs veien du velger. Du kan gjerne ta i bruk kalkulator.

Husk at du ikke kan gå oppover eller tilbake der du kom fra.

Du skal starte med en verdi på 100 på kalkulatoren. Målet ditt er å velge en vei som resulterer i størst verdi når du er ferdig. Du kan også benytte deg av kladdeark på neste side for å vise en eventuell utregning og svarene dine underveis.

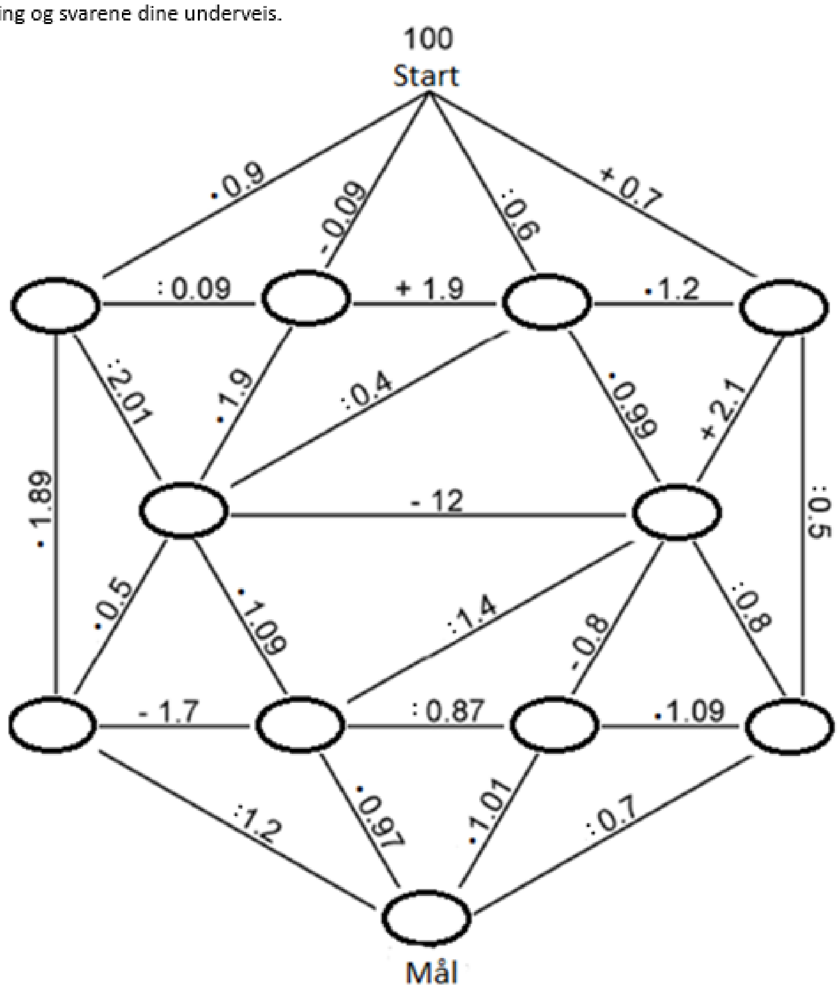

Figure 6: Decimal labyrinth

In the second part of the assessment, participants encountered more complex problems and were permitted to use calculators for solving them. However, only task 1 - part 2 (see Figure 6.) specifically required a calculator. This task was introduced to evaluate participants' decision-tree abilities and their general understanding of mathematical symbols. The objective was to navigate through the hexagon, generating the largest number possible. This task could not be analyzed using the chi-square test, so the Mann-Whitney U test was employed to assess the results.

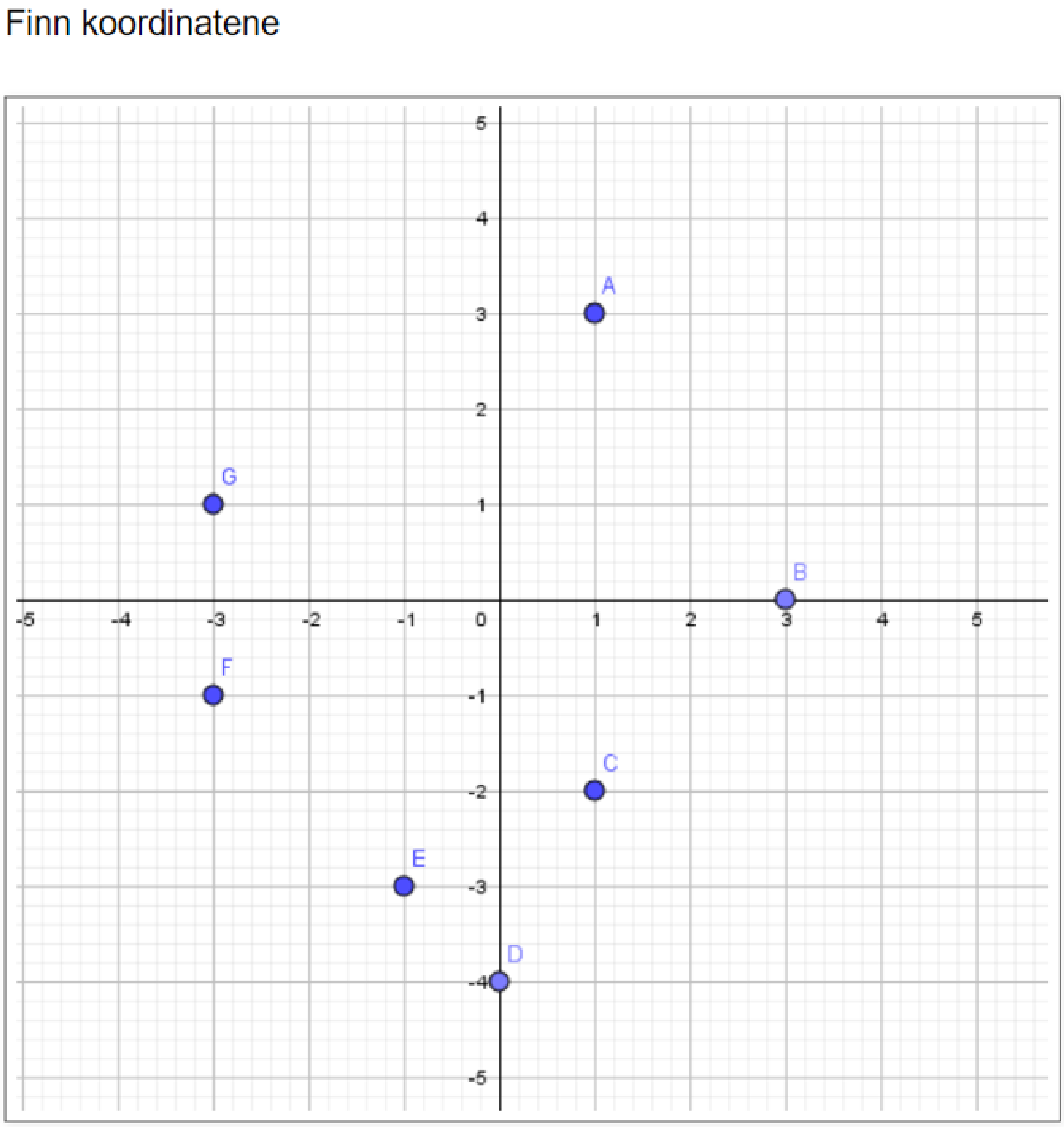

Figure 7: Coordinate plane

Oppgave A) - Finn Koordinatene

TASK 2A

Skriv inn riktig koordinat for de ulike punktene i koordinatsystemet på forrige side.

A: (1, 3) ________

B: ____________ E: ____________

C: ____________ F: ____________

D: ____________ G: ____________

Oppgave B)

TASK 2B

Tegn inn disse koordinatene i koordinatsystemet på forrige side.

H $(-3, -2)$ I $(2, -2)$ J $(2, 2)$ K $(-3, 2)$

Hva slags firkant får du hvis du trekker opp linjestykkene HI, IJ, JK og KH?

TASK 2C

Svar: ____

Figure 8: Coordinate plane tasks

Figure 7 and 8 displays the second to last task, illustrating the increase in complexity from part 1 to part 2. This task, centered around functions, geometry, and coordinate systems, assesses the participants' overall proficiency in these three areas of knowledge.

Oppgave 3 – Number lines

Hva blir de tre neste tallene i følgende tallrekker:

1)	0	1	2	3	4	5	6	
2)	90	100	110	120				TASK 3.2
3)	40	45	50	55				TASK 3.3
4)	43	45	47	49				TASK 3.4
5)	4	5	7	10				TASK 3.5
6)	2	2	4	6				TASK 3.6
7)	15	30	60	120				TASK 3.7
8)	4,5	4,6	4,7	4,8				TASK 3.8
9)	6,5	8	9,5	11				TASK 3.9
10)	6,5	8,5	10,5	12,5				TASK 3.10
11)	3,5	3,55	3,6	3,65				TASK 3.11
12)	6,2	12,4	24,8	49,6				TASK 3.12
13)	4	2	1	0,5				TASK 3.13
14)	9,5	9,5	19	28,5				TASK 3.14

Figure 9: Number lines

The last task on the test (Figure 9), was added to test the pattern-recognition abilities of the participants. The task is to fill in the next three numbers on a number line. One example is added for clarification. The level of complexity varies in this task, but the lines in general gets increasingly more complex.

4. Results

4.1 Non-parametric test – Chi Square

The administered test consists of two sections: Part 1 and Part 2. Part 1 comprises six tasks, which are further divided into 15 subtasks, while Part 2 includes three tasks split into 17 subtasks (See below for table 2). Although each task is treated individually, many share common mathematical aspects, such as mental calculation featured in tasks 6a, 6b, and 6c (See Appendix, Part 1). The Chi-Square test was employed to analyze 31 out of the 32 subtasks, representing the majority of the results. The remaining subtask, which was a larger task (See figure 6 methodology), was not suitable for analysis using the Chi-Square test. The remaining task was analyzed using the Mann-Whitney-U test.

A Chi-Square test is a statistical method used to see if there is a significant connection between two categorical (non-numerical) variables. It helps to find out if there is a difference or relationship between the two variables or if they are just happening by chance.

This test is done by comparing the expected results (what we'd expect to see if there was no difference between the variables) to the actual results. The expected values are computed based on the joint rates of correct/incorrect answers from the two groups, hence considering the relative difficulty of tasks overall. A value known as the Chi-Square statistic is calculated based on the difference between these values.

If the Chi-Square value is large enough, we can say that there is a significant relationship or difference between the variables, and it is not just due to chance. The conducted Chi-Square tests will show statistical differences between the two groups while accounting for randomness on multiple-choice questions. Applying this method to the test enables measuring the statistical significance between the two groups.

Figure 10 shows task 2b from part 2, a sample task from data collection instrument. A sample computation of chi-square test for this task is illustrated in table 2 below. In this particular task, the non-chess group had 5 students answering correctly whereas chess group had 13 students. Based on these figures, one would expect an equal rate of correctly answering in the two groups (9 students), had there been no association between chess playing and not playing in relation to performance in this task. Because the probability of observing the difference (of 5 students to 13 students in the two groups) due to purely chance was too low (the p-value = 0,001604, was smaller than the benchmark value of alpha = 0,05), we concluded that the groups differed significantly in this task:

Oppgave B)
Tegn inn disse koordinatene i koordinatsystemet på forrige side.
H (−3, −2)   I (2, −2)   J (2, 2)   K (−3, 2)

TASK 2B

Figure 10: Task 2b from part 2 of the instrument (see Appendix for entire task).

Task 2b of part 2	# of correct answers	# of incorrect answers
Observed frequencies		
Non-chess playing group	5	9
Chess playing group	13	1
Expected frequencies		
Non-chess playing group	9	5
Chess playing group	9	5
p-value	0,001604	
Alpha	0,05	
Test – statistic (Chi-square value)	9,955556	

Table 1: Sample computation of chi-square test for task 2b in part 2.

	Task Number	P-Value	Chi Sq Value	Alpha Value	Statistical Significance	Outperformance
Part 1:	Task 1	0,138	2,191	0,05	No	Chess
	Task 2			0,05	No	Equal amount correct
	Task 3			0,05	No	Equal amount correct
	Task 4	0,138	2,191	0,05	No	Chess

	Task 5a	0,445	0,058	0,05	No	Chess
	Task 5b	0,114	2,488	0,05	No	Chess
	Task 6a.1	0,142	2,153	0,05	No	Chess
	Task 6a.2	0,28	1,166	0,05	No	Chess
	Task 6a.3	0,066	3,36	0,05	No	Chess
	Task 6b.1	0,03	4,666	0,05	Yes	Chess
	Task 6b.2	0,058	3,589	0,05	No	Chess
	Task 6b.3	0,114	2,488	0,05	No	Chess
	Task 6c.1			0,05	No	Equal amount correct
	Task 6c.2	0,126	2,333	0,05	No	Chess
	Task 6c.3	0,058	3.589	0,05	No	Chess
Part 2:	Task 2a	0,662	0,19	0,05	No	School
	Task 2b	0,001	9,955	0,05	Yes	Chess
	Task 2c	0,255	1,292	0,05	No	Chess
	Task 3.2			0,05	No	Equal amount correct
	Task 3.3			0,05	No	Equal amount correct
	Task 3.4			0,05	No	Equal amount correct

	Task 3.5	0,356	0,848	0,05	No	Chess
	Task 3.6	0,698	0,149	0,05	No	Chess
	Task 3.7	0,029	4,761	0,05	Yes	Chess
	Task 3.8	0,065	3,39	0,05	No	Chess
	Task 3.9	0,043	4,093	0,05	Yes	Chess
	Task 3.10	0,035	4,412	0,05	Yes	Chess
	Task 3.11	0,012	6,3	0,05	Yes	Chess
	Task 3.12	0,0006	11,63	0,05	Yes	Chess
	Task 3.13	0,0001	14,285	0,05	Yes	Chess
	Task 3.14	0,0016	9,955	0,05	Yes	Chess

Table 2: Computation of all tasks, with the exception of Task 1 part 1, combined.

The results of the study are presented in **Table 2** with various columns, including task number, p-value, chi-Square value, alpha value, statistical significance. To achieve statistical significance, the alpha value was set to 0.05, and the p-value for the respective task must be below the alpha value of 0.05. Furthermore, an "Outperformance" column is present, indicating the group with a higher score than the other. While the results were not significant in every instance, this column clarifies the scoring system. For a more in-depth examination of the results, the p-value or chi-Square value can be consulted, as they provide more specific information regarding statistical significance. No Chi-Square analysis is conducted for the groups when they have an equal number of correct answers (meaning either all participants answered the task correctly, or they achieved the same number of correct answers on the task).

In Part 1 of the study, there were no statistically significant results, expect for task 6b.1 (See Appendix), but the chess group outperformed the school group in most tasks. In Part 2, the chess group continued to outperform the school group, with several tasks demonstrating statistical significance. Task 2a was the only task in which the school group outperformed the chess group, however the result was not statistically significant.

Statistically significant results were found in the following tasks: Task 6b.1, Task 2b, Task 3.7, Task 3.9, Task 3.10, Task 3.11, Task 3.12, Task 3.13, and Task 3.14 (See Results). These tasks showcased the chess group's overall performance, particularly in the more complex tasks, suggesting that the chess group's skills transferred effectively to various mathematical tasks.

The findings of this study provide valuable insights into the performance of the chess group and the school group on various mathematical tasks. The results suggest that there may be a correlation between chess-playing abilities and mathematical skills, particularly in tasks that are more complex and challenging. One notable pattern observed in the results was the chess group's performance on tasks involving number lines, with the mathematical abilities of pattern recognition. These tasks seem to indicate a transfer of skills from chess to mathematical problem-solving, as chess requires strong pattern recognition and strategic thinking. The chess group's ability to excel in these tasks demonstrates that their chess expertise may indeed have a positive impact on their mathematical skills.

Another interesting observation was the chess group's performance on tasks later in the test. Their p-values tended to decrease, implying that the chess group's performance became increasingly more significant as the test progressed. This could suggest that the chess group had better stamina, focus, and or time management skills, which allowed them to maintain their performance throughout the test. Additionally, this suggests that the chess group demonstrated a superior comprehension of intricate tasks, as the test's challenges progressively grew in complexity.

Despite the chess group's overall performance, it is important to note that the school group outperformed the chess group in one task involving a coordinate system. Though not statistically significant, this result challenges the assumption that chess players should excel at coordinate system tasks due to the nature of chessboard navigation. This finding highlights the need for further research to understand the relationship between chess expertise and specific mathematical skills, however it further shows indication on math specific knowledge about coordinate systems, meaning that a different task with similar mathematical abilities such as Task 2 – part 1 (See Appendix), would yield a different outcome.

The findings of this study suggest a possible connection between chess-playing abilities and enhanced mathematical performance. The chess group's success in more challenging tasks and their consistent performance throughout the test point to potential benefits of chess training on cognitive and problem-solving skills. However, more research is needed to confirm these correlations and explore the nuances of skill transfer between chess and mathematics.

The chess group outperformed the school group in 24 out of 25 tasks, while 6 tasks resulted in a "tie." Furthermore, 9 out of 25 of these outcomes were statistically significant results. Most statistically significant results were observed in the more challenging tasks of the test. In Part 2, tasks 3.7 to 3.14 (See appendix) involved more difficult number lines for the participants to complete. It is worth noting that some children faced difficulties in finishing the test on time, indicating a potential difference in time management and speed between the groups. While this study does not include subjective observations, any conclusions drawn regarding the results of Table X remain speculative. However, the observed increase in the Chi-Square value as the test advanced suggests that this may be a plausible explanation.

Furthermore, a notable aspect of the latter part of the test involves the various skill transfers assessed. The final task, in which the chess group achieved their highest score, required pattern recognition. To explain the increased variance in the latter half, it is also reasonable to consider the impact of these skill transfers.

The school group outperformed the Chess group in 1 out of 25 tasks, with 6 tasks ending in a "tie." The task was not statistically significant but is worth noting that it involved a coordinate system task (See appendix, task 2a part 2), which theory suggests chess players should excel at as one of the more specific skill transfers.

Interestingly, not all tasks showed a difference in mathematical abilities between the two groups. This could be due to various factors, such as the possibility that skill transfer does not occur in every instance, which is likely one contributing factor. Another consideration is the range of task complexities used to assess differences. Some tasks may have been too simple, causing both groups to solve them easily and preventing the test from highlighting any distinctions in their abilities. Conversely, overly challenging tasks may also lead to similar results, as none of the participants would be able to solve them correctly, resulting in minimal differences in the comparative aspect. Part 2 of the test was likely the difficulty that tested differences the best as results was more varied.

4.2 Non-parametric test – Mann Whitney U test

The Mann-Whitney U test is a nonparametric statistical test used to compare two independent samples to determine if there is a significant difference between their distributions. The test is particularly useful when the data do not meet the assumptions required for parametric tests.

The Mann-Whitney U test was conducted on Task 1 in part 2 of the mathematical test. Task 1 was not suitable for the Chi-Square test and was one of the longer tasks. The reason why it was not suited is due to its nature of the task having continuous scores and not a direct “correct/false” relationship.

Presented below are the results from after the conducted Mann-Whitney U test:

Decimal Labyrinth task				Ranks	
	School Group	Chess Group		School Group	Chess Group
1	246,5	163,5		18,5	12
2	449,5	246,5		22	18,5
3	288	103,5		20	7
4	220,2	3706,3		16,5	28
5	0	2922,2		1,5	26,5
6	101	141,8		4,5	10
7	322	2922,2		21	26,5
8	83,3	914,3		3	24
9	101	220,2		4,5	16,5
10	163,3	2648,3		11	25
11	0	101,1		1,5	6
12	165,8	141,5		13	8,5
13	868,4	141,5		23	8,5
14	183,5	171,5		15	14
$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1$			Ranksum R1 & R2	175	231
			Sample size	14	14
$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$			Test statistic (Smir of U1 & U2)		70
			Onetailed Critical value (14,14)		61

			U2= 70	U1= 126	

Table 3: Computation of Mann-Whitney U test on Task 1, part 1.

Because 70 is bigger than 61, we conclude the difference is not significant between the two groups.

A Mann-Whitney U test was performed to evaluate whether chess group scores differed by school group scores. The results indicated that there was no significant difference between the chess group and the school group.

The conclusions from **Table 3.** indicate that the findings are not significant. However, it is worth noting that the chess group achieved a considerably higher average score, revealing interesting results. The outcomes display some extreme differences, with a few chess players finding a much more optimal route than the control group. It is important to highlight that four values scored far above 1000 in the chess group, while the school group had none. This suggests that four students from the chess group comprehended and completed the task, attaining a high score compared to the average. The Mann-Whitney U test does not consider average scores but instead separates the groups using a point system based on the distribution of placements among both groups. Due to the test's nature, no statistical difference was detected, even though the chess group exhibited higher overall performance in terms of ratings.

5. Discussion

5.1 Summary of findings

Overall, the findings from the results chapter were in favor that there is an association between playing chess and solving mathematical tasks. The chess group outperformed the school group in 24/25 tasks. Moreover, the chess group preformed over statistical significance on nine tasks. The Chi-Square test was employed to analyze the majority of the tasks, while the Mann-Whitney U test was used for one specific task.

The Discussion chapter will cover more of the range of why, and how these tasks tested implementations of known transfers between the domains. However, some tasks revealed skill transfer from chess to mathematical problem-solving, particularly pattern recognition and strategic thinking. The chess group's performance seemed to improve as the test progressed, potentially due to better stamina, focus, or time management skills.

5.2 Interpretation of results

5.2.1 Skill transfer between chess and mathematics

In the theory chapter, certain specific and non-specific transfers were discussed. This sub-chapter aims to explore the potential outcomes of the findings in connection to these transfers, offering a more comprehensive understanding of their implications.

Specific

Coordinate Systems

I initially expected the chess group to outperform the control group in coordinate systems, one of the main transferable skills I had anticipated. However, the statistical results indicated that this was one of the few specific domains where the control group could compete in terms of performance (See task 2- part 1 and task 2- part 2, Appendix). It is important to consider that both coordinate system tasks in the test were relatively simple, making any differences between the groups volatile to randomness. None of the simpler tasks resulted in one group statistically outperforming the other, which makes it challenging to draw conclusions from findings that the level of complexity does not reach the heights of the participants potential. Task simplicity does not hinder transfer; however task simplicity hinders the participants of extending their knowledge above the other group, making the simple tasks difficult to compare.

Combinatorics

Task 5 - Road Choices, part 1 (See Appendix) was a combinatorial task where participants were asked to identify the number of possible roads between three houses. This task did not show a statistically significant difference; however, the chess group performed slightly better overall. As one of the more challenging tasks, it demonstrated that combinatorics might not transfer as effectively as other skills when there is a general lack of mathematical fundamentals. Some of the children had visual lines written all over their task, making it clear that they attempted to count the possible roads instead of giving it a shoot to answer with multiplication for instance. This approach might have led to more careless errors, as not many participants answered correctly. This task showed interesting results in terms of which fields that transfer more than others. Combinatorics seem to not be a near-transferable skill within mathematics, especially when there is a lack of mathematical knowledge to solve the task.

Decision Trees

The Decimal Labyrinth task (See Task 1 part 2, Appendix), which focused on decision trees incorporating the order of operations, saw the chess group performing notably well. Their average score surpassed that of the control group by a considerable margin. However, the Mann-Whitney U test indicated that the difference was not statistically significant. On average, both the chess and control groups had similar performance on this task, with scores between 100 and 300. A few members of the chess group, however, demonstrated a complete understanding of the task and achieved exceptionally high scores (around 3700), raising their group's average significantly above the control group. These results were fascinating, as evaluation and backward progression are crucial components of chess calculations. The task demanded that children investigate various paths and identify the best decision tree to pursue. Nonetheless, the Mann-Whitney U test did not yield statistically significant outcomes, as it revealed more extreme differences across the spectrum rather than a general group average.

Pattern recognition

In the final task of the test (See task 3, part 2, Appendix), participants were evaluated on their ability to recognize and complete patterns. The chess group displayed a statistically significant better performance compared to the control group. As chess centers around identifying patterns, top players often recognize them more readily than less proficient players. This skill's importance in chess translates effectively into the mathematical test, where the chess group excelled in completing number sequences compared to the control group. During the test, participants were tasked with recognizing and completing various patterns, a crucial aspect of both chess and mathematics. The chess group, possessing enhanced pattern recognition abilities, significantly outperformed the control group. This outcome emphasizes the transferable skills gained through playing chess, particularly in terms of pattern identification.

Top chess players excel at detecting patterns on the board, allowing them to anticipate opponents' moves and devise strategic plans. This expertise effectively carries over to mathematics, where pattern recognition is vital for problem-solving and understanding diverse mathematical concepts.

The test results highlight the potential benefits of engaging in chess to boost cognitive abilities, particularly in the context of mathematics. By honing their pattern recognition skills, individuals in the chess group were better able to complete number sequences, showcasing the applicability of chess-based learning. Additionally, their superior performance on the last task underscores the possible significance of time management, which may have been a contributing factor to the chess group's impressive results on this task.

<u>Non-specific</u>

Logical Reasoning

A non-specific transfer that could be assessed in the general mathematical test is the chess group's overall performance compared to the school group. The chess group outperformed the school group, indicating that they are better at mathematics than the control group. Logical reasoning, a crucial factor in solving mathematical problems, emerges as a clear non-specific transfer evident in the results.

Attention to Detail

Abel’s puzzles (See task 1, part 1 Appendix) consisted of a straightforward figure-reasoning task, which I initially anticipated everyone would answer correctly. However, some participants from the control group incorrectly identified the wrong figure as the answer, likely due to a reading or visual error on their part. This discrepancy suggests that the chess group (who all answered correctly) may demonstrate greater patience and a heightened attention to detail. They avoid careless mistakes by carefully reading the task and thoroughly examining their options before deciding. Furthermore, Abel's puzzles suggested that chess players demonstrated an enhanced aptitude for figure-reasoning tasks overall. Although the outcomes were not statistically significant, their performance was superior in this regard. Additional research is required to determine the specific transferable skills between both domains, but figure-reasoning tasks appear to be a promising mathematical ability to explore further.

Time Management

The chess group exhibited signs of being marginally better at time management than the control group. This observation is based on instances where certain tasks were left incomplete by some participants in the control group. Several factors may explain this phenomenon. One possible reason is the increasing complexity of the tasks as the test progressed, prompting some participants to skip tasks, such as task 1 - part 2 (See **Figure 6** in Methodology) or later in the test, Task 3 - part 2 (See **Figure 9** in Methodology). Another contributing factor could be the limited time available for some participants, suggesting that the stress associated with a chess clock might influence their ability to manage time during a mathematical test, indicating a potential transfer between these two domains.

5.2.2 Task complexity and performance

Many of the more challenging tasks appeared later in the test. For instance, tasks 2 and 3 in part 1 (See Appendix) were solved by all participants. The chess group tended to achieve statistically significant (or nearly significant) results on more complex tasks. This could be interpreted as chess players being more capable of solving difficult math problems, making it worthwhile to test even harder tasks in future studies, particularly those involving out-of-the-box problem-solving in math.

It should be noted that some of the more advanced mathematical tasks did not show a statistically significant difference (See task 6, part 1, **Table 2**, Results). However, the majority of tasks that exhibited statistical significance were the more complex ones at the latter half of the test.

5.2.3 Time management and test-taking skills

The chess group children outperformed the school group throughout the test, but most of the statistically significant findings emerged towards the end. Some of the transfers discussed in the theory chapter addressed time management and test-taking skills. Chess, being a competitive game, can last several hours or even days with longer time controls. One possible interpretation of the statistical findings is that chess players are faster and more accurate than non-chess players in solving mathematical tasks, particularly over an extended period, such as an hour. Another interpretation is that chess players may be more motivated to complete the tasks, as some children from the school group exhibited tendencies to skip tasks that were either too difficult or text heavy (See **Table 3**. Results).

The significance of time management as a factor might stem from the fact that participants were given only an hour to solve all 32 subtasks. While some tasks could be completed in a matter of seconds, others might take up to 10 minutes to produce a perfect answer. Chess players may be more adept at making decisions about their answers, knowing that more tasks lie ahead, allowing them to provide satisfactory responses while maintaining a high average score on the test.

5.3 Comparison with previous research

Previous research has yielded both positive and mixed results when assessing the impact of chess instruction on academic performance. Most studies mentioned in the "summary of previous research" chapter report positive outcomes for chess instruction as a replacement or supplement to regular math instruction. This study, however, does not examine chess instruction as a replacement but investigates whether existing chess players perform better in mathematics than the average school child who receives chess instruction.

The findings of this study align with previous research, showing statistically significant differences favoring the chess group. Unlike previous studies, this research concludes that there is a statistically significant difference between chess players and non-chess players in terms of time management and mathematical tasks involving number lines. Other instances of prior research tend to generalize findings into "mathematics," while the data from this study indicate that chess players outperform non-chess players in all but one of the mathematical tasks tested.

In summary, this study supports the notion that chess players exhibit advantages in certain mathematical tasks and time management compared to their non-chess-playing counterparts, echoing the findings of previous research.

5.4 Limitations of the study

The study primarily lacks a sufficient number of participants and could have potentially adopted an interpretative approach, examining the two domains and drawing conclusions based on interviews regarding the same tasks. Despite the limited number of participants, the study's findings align with much of the previous research conducted globally, indicating that there is indeed some association between chess and mathematics.

The limitations stem from employing a small sample size for non-parametric statistical tests. While non-parametric tests are useful in situations where assumptions about the underlying population distribution cannot be met, These tests do not rely on specific assumptions about the shape or parameters of the population distribution, such as normality. Instead, non-parametric tests are based on ranks or other distribution-free measures, making them more robust and flexible when dealing with data that may not adhere to the standard distribution assumptions. As a result, they can be applied to a wider variety of situations, particularly when dealing with non-normal, skewed, or ordinal data. They possess less statistical power than their parametric counterparts. Additionally, they offer reduced precision and can be challenging to interpret. The difficulty in interpretation arises from their volatility, where the results may not reflect the factors the researcher intended to investigate. While encountering unexpected results is often the driving force behind research, drawing conclusions from such findings can be challenging.

For example, it was surprising to see the school group outperform the chess group in coordinates. However, some noteworthy findings exceeded my expectations, such as time management and speed, some crucial transfers that may very well stem from playing chess.

One could argue that this study suggests chess players are not necessarily better at coordinate systems than non-chess players. However, given the small sample size and the fact that only 2 out of 32 tasks specifically tested coordinate systems, it is difficult to definitively conclude this. Another factor was the task simplicity of these tasks which might have been different with more complex tasks. This limitation applies to all results derived from the mathematical test, as a small sample size can lead to increased speculation about the reasons behind the observed outcomes. Various factors could have contributed to the results, such as geographical differences or the timing of when the tasks were completed - with chess players solving the tasks in the evening while the school group worked on them during the first lecture of the day in a school setting. Speculations about performance differences can be made in either direction. Nonetheless, the most evident finding from the mathematical test was the chess group's ability to solve the tasks both accurately and within the allotted time.

The study would strengthen itself with the inclusion of more participants, making it possible to include parametrical tests. Sadly, this was not possible for this master study but is encouraged for any readers interested in finding out more about the correlation, relationship, or connection between chess and mathematics.

The study could be adapted to have a more substantial influence on the practical aspects of education. Currently, it does not investigate chess instruction as a replacement or supplement to mathematical education, but rather examines whether engaging in chess as a hobby enhances certain transfers between the two domains. The study would be more impactful in the practical realm if a group received regular chess instruction, with mathematical abilities assessed before and after the intervention. However, due to the constraints of a master's degree in terms of time and resources, implementing such a design was not feasible.

It is noteworthy that the chess group from Oslo exhibited signs of achieving higher scores than both the chess group and the school group from Kristiansand. This observation implies that the geographical location might have influenced the study's outcomes. It is important to recognize that the chess group was split between Oslo and Kristiansand before being combined into a single larger group. The study does not take into account average scores from national tests from the children’s schools, but focusing solely on whether a participant has played chess for at least six months or more.

For future research, participants from both the control group and the main group could be selected from various locations throughout Norway, reducing the potential impact of geographical differences. This approach would enhance the generalizability of the results, making them more representative of the broader Norwegian population.

5.5 Implications for practice

Upon examining the study's findings, it is evident that a correlation exists between playing chess and solving mathematical tasks. However, the study does not conclusively demonstrate the value of substituting math or any other subject with chess instruction. Nevertheless, incorporating chess as an alternative to other board games or activities in everyday school life may enhance children's work speed, problem-solving skills, time management, competitiveness, and other game theory transfers, although more research needs to be conducted to hold this statement on firm ground.

Chess, as a social activity, encompasses more than just mathematical thinking, including non-specific transfers such as concentration and decision-making, which are valuable in work-life. Cultivating the ability to make rational decisions is a significant asset in professional life, highlighting the importance of chess not only in mathematics but in other subjects as well.

It is worth noting that while not all chess players are interested in math, most are interested in chess itself. This suggests a common pattern where having a hobby may contribute to improved results on mathematical tests. Playing chess can aid children in developing essential qualities such as sportsmanship, respect, critical thinking, resilience, and patience, which are similar to the values promoted by other subjects in Norwegian schools, such as physical education or gymnastics.

The United States, France, and Argentina provide chess as an elective subject, with some institutions even mandating compulsory classes in the discipline. (Gobet & Campitelli, 2001). Considering the outcome of this study and the results that there is an improvement in some transfers between the chess group and solving mathematical tasks. Chess should be considered as an artifact to show certain mathematical skills. However, this study alone is not enough to make large conclusions about being an addition to the national curriculum, chess as a school activity should certainly not be underestimated by the results of this study. Furthermore, the inclusion of chess as an optional subject could be a way to increase mathematical understanding among children alongside motivation and reduced boredom.

Personally, I will incorporate chess into my classroom as a supplement to other social activities. However, I would exercise caution before considering the replacement of standard math education with chess instruction, as there is insufficient scientific evidence to determine which skills chess instruction can and cannot replace. Nonetheless, utilizing chess as an activity in school is feasible and recommended, considering the synthesis of prior research and the data from this study. Integrating chess into the educational environment can provide students with a unique opportunity to engage their minds in various ways. Chess encourages strategic thinking, pattern recognition, and adaptability, which can have positive impacts on their cognitive development. Additionally, it fosters a sense of camaraderie and teamwork, as students can collaborate and compete and learn from each other's experiences, further enhancing their interpersonal skills. Inclusion of chess in the curriculum can also help educators create a more dynamic and interactive learning experience. By incorporating chess-related activities, teachers can stimulate students' curiosity, allowing them to make connections between the game and the concepts they are learning in other subjects. For instance, exploring chess strategies could lead to a discussion about historical battles or famous leaders, while calculating possible moves can help reinforce mathematical principles. Moreover, chess can serve as a valuable tool to improve students' focus and perseverance. As they invest time and effort into understanding the game's intricacies, they learn to overcome obstacles and adapt to changing situations. These skills are transferable to various aspects of their lives, including academic performance, career aspirations, and personal growth.

However, it is essential to maintain a balanced approach to education. While chess can indeed offer numerous benefits, it should not be considered a substitute for traditional subjects as of yet. Instead, it should complement the existing curriculum, providing students with an enriching and diverse learning experience.

Incorporating chess into the educational setting can yield numerous advantages for students, ranging from cognitive development to the enhancement of interpersonal skills. By carefully integrating this activity into the curriculum, educators can create a more engaging and well-rounded learning environment that helps students reach their full potential.

6. Conclusion

The main research question were;

- ***Is there a relationship between playing chess and solving mathematical tasks?***
- ***What causes the relationship between playing chess and the ability to solve mathematical tasks?***
- ***Which are the main transferable abilities that connects chess and mathematics?***

Through this study, I attempted to explore the relationship between these two domains, while looking at results from the conducted tests.

The results of the study cannot draw any clear conclusions between what the relationship between chess and mathematics is, however, it indicates findings that shows results in improved test and task solving abilities between the two domains. Through the suggested transfers; actively playing chess results in an overall general better test-taking ability and should therefore be taken seriously as an implication in school. Thus as a conclusion the data of this study suggest that there is a positive relationship between playing chess and solving mathematical tasks.

The cause of the relationship is largely based on potential transfers between domains. Being non-specific or specific. Theory suggest that non-specific transfers rarely happen if the distance of the domains are too far (Detterman,1993). With this in mind, the domains of chess and mathematics are closer than first expected as the results indicate some form of transfer between the domains across multiple mathematical abilities, both specific and non-specific.

The main findings of this study show an indication on a general higher performance on pupil that actively plays chess compared to children that does not actively play chess. The most statistically significant findings were the chess players results on the latter part of the test, showing indications on test-taking skills, logical reasoning, and pattern-recognition abilities. These findings show that working with chess on a more competitive level could improve some aspect of one's mathematical performance. Scoring well on mathematical tests is not necessarily the main goal, however it is a useful skill in working life, as timeframes comes in one's everyday life.

Overall, the result from this study is eye opening in terms of transfer abilities between two domains. The results shows that chess has its place in the Norwegian educational system as it promotes abilities that expand on mathematical thinking. It is however noteworthy that with the current lack of studies involving the association between chess and mathematics, more research must be done on this field to be certain that the findings hold reliable factors and are not just random differences between the two groups.

Despite the chess group's overall superior performance, it is important to note that the school group outperformed the chess group in one task involving a coordinate system. Though not statistically significant, this result challenges the assumption that chess players should excel at coordinate system tasks due to the nature of chessboard navigation. This finding highlights the need for further research to understand the relationship between chess expertise and specific mathematical skills. In conclusion, the findings of this study suggest a possible connection between chess-playing abilities and enhanced mathematical performance. The chess group's success in more challenging tasks and their consistent performance throughout the test point to potential benefits of chess training on cognitive and problem-solving skills. However, more research is needed to confirm these correlations and explore the nuances of skill transfer between chess and mathematics.

I encourage any readers interested in continuing this research to perform a similar conducted test, with a larger group. Making it possible to conduct parametrical test or using fewer transfers to test. For instance, only coordinate systems, figure-reasoning and pattern recognition tasks, this would indicate some of the few potential transfers between the two domains and clear cut their advantages between the two groups more clearly.

In conclusion, this study highlights the potential benefits of incorporating chess as a cognitive training tool to enhance mathematical test-taking skills. The association found between chess and improved mathematical abilities suggests that the strategic and analytical aspects of chess can foster a stronger foundation for tackling complex mathematical tasks. Integrating chess into an educational setting creates a fun, engaging, and effective way to develop critical thinking, problem-solving, and analytical skills. These benefits extend not only to students' mathematical abilities but also to a broader spectrum of their academic and professional pursuits.

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8. Appendices

8.1 --------Del 1 ---------

Navn: _______________

Gruppe: _____________

Alder: _______________

Informasjon

Prøvetid	Prøven varer i 1 time. Det er lov å levere før.
Hjelpemidler	Del 1: Det er ingen tillate hjelpemidler utenom skrivesaker og kladdeark. Del 2: Skrivesaker, kladdeark og kalkulator er lov.
Fremgangsmåte og forklaring	Prøven er bestående av to deler. Del 1: består av seks (6) oppgaver, og du skal svare på disse ved å krysse av i riktig rute eller ved å fylle inn/skravere et antall ruter for å få riktig svar. Det er lov å skrive på prøven om du ønsker å regne ut noe. Del 2: Består av tre (3) oppgaver. I del 2 kan du benytte kalkulator. Skriv med penn.

Innhold

Kartlegging av sjakk og matematikk

I denne kartleggingen skal du krysse av for hvilken påstand som passer best for deg. Du skal bare sette ett kryss per spørsmål eller fylle inn boksene hvor det passer seg.

Har du spilt sjakk før?

- ○ Ja
- ○ Nei, aldri

Kan du reglene i sjakk?

- ○ Ja
- ○ Nei
- ○ Kan nesten alle reglene, men er usikker på noen
- ○ Vet ikke

Liker du å spille sjakk?

- ○ Ja, liker det godt
- ○ Synes det er ok
- ○ Nei, synes ikke sjakk er noe gøy
- ○ Vet ikke

Hvor ofte spiller du sjakk?

- ◯ Hver dag
- ◯ 3-5 ganger i uken
- ◯ 1-2 ganger i uken
- ◯ 1 gang i måneden
- ◯ Mindre enn 1 gang i måneden
- ◯ Har ikke spilt sjakk før

Har du spilt sjakk aktivt i sjakklubb i 6 måneder eller lenger?

- ◯ Ja
- ◯ Nei

Er du rangert med FIDE- rating?

- ◯ Har ikke FIDE-rating
- ◯ 0-600
- ◯ 600-800
- ◯ 800-1000
- ◯ 1000-1200
- ◯ 1200-1400
- ◯ 1400-1600
- ◯ 1600-1800
- ◯ 1800+

Har du rating på Chess.com eller Lichess.org? Hva er ratingen din på hurtigsjakk (rapid) eller lynsjakk (blitz)?

- Har ikke rating på Chess.com eller Lichess.org
- 0-600
- 600-800
- 800-1000
- 1000-1200
- 1200-1400
- 1400-1600
- 1600-1800
- 1800-2000
- 2000-2100
- 2100-2200
- 2200+

8.2 Oppgave 1 – Abel's puzzles

TASK 1

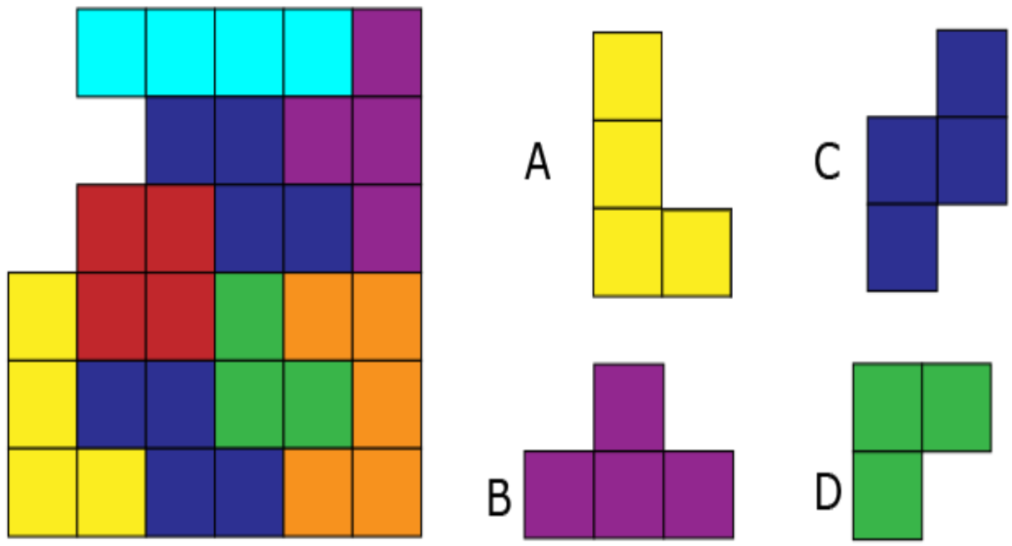
Abel legger et puslespill, men mangler én

brikke for å bli ferdig.

brikke for å bli ferdig.

Hvilken brikke mangler Abel for å bli ferdig?

- ○ A
- ○ B
- ○ C
- ○ D



TASK 2

8.3 Oppgave 2 – Treasure hunt

Espen har laget et skattekart. Han har bestemt at skatten skal graves ned i rute E5.

Sett kryss I ruten hvor skatten skal graves ned.

TASK 3

8.4 Oppgave 3 – Sheep

Bestefaren til Lasse har 20 sauer.
I løpet av våren fikk sauene lam.

6 sauer fikk 1 lam hver.
12 sauer fikk 2 lam hver.
2 sauer fikk 3 lam hver.

Hvor mange lam fikk sauene til sammen?

Regn ut i rutenettet under. Sett to streker under svaret ☺

TASK 4

8.5 Oppgave 4 – Music notes

Her ser du hvor mange slag noen noter har.

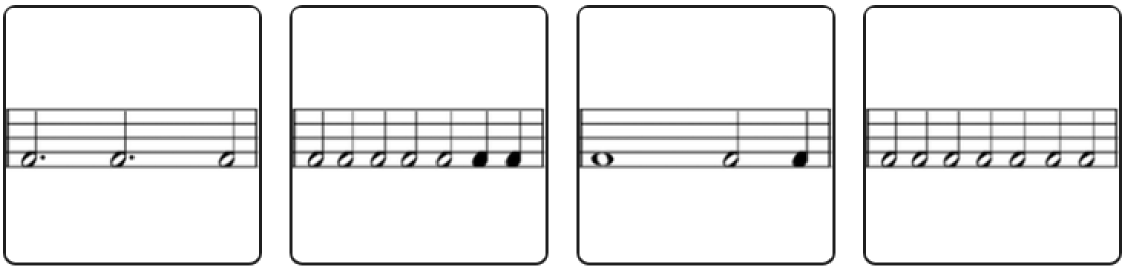
4 slag

3 slag

2 slag

1 slag

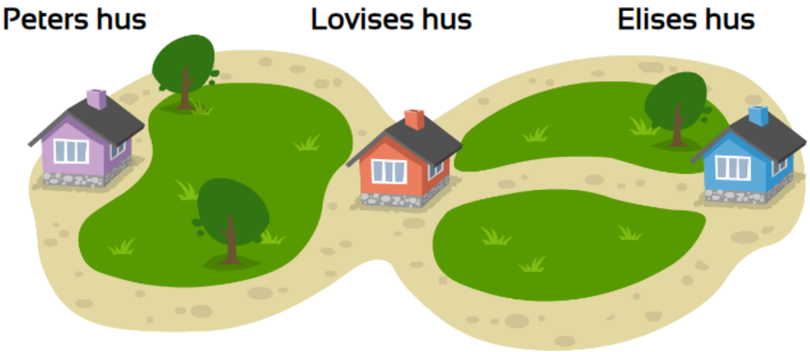
Hvilket av notebildene viser 7 slag til sammen?



8.6 Oppgave 5 – Road choices

TASK 5a

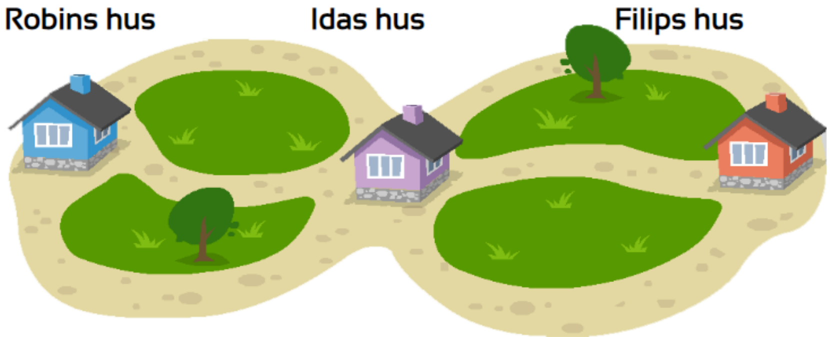
Hvor mange forskjellige veier er det fra Peters hus til Elises hus forbi Lovises hus?



☐ forskjellige veier

TASK 5b

Hvor mange forskjellige veier er det fra Robins hus til Filips forbi Idas hus?



☐ forskjellige veier

8.7 Oppgave 6 – Fill in the squares

Fullfør regnestykkene.

Tallene skal bare brukes én gang i løpet av hvert regnestykke. En kan eksempelvis ikke ha 2·2 i første regnestykke, men en kan bruke 2 én gang i alle tre regnestykker.

0 1 2 3 4 5 6 7 8 9

$\square \cdot \square + \square = 12$ TASK 6a.1

$\square \cdot \square + \square = 30$ TASK 6a.2

$\square \cdot \square + \square = 20$ TASK 6a.3

Fullfør regnestykkene.

Tallene skal bare brukes én gang i løpet av hvert regnestykke. En kan eksempelvis ikke ha 2·2 i første regnestykke, men en kan bruke 2 én gang i alle tre regnestykker.

0 1 2 3 4 5 6 7 8 9

$\square \cdot \square - \square = 30$ TASK 6b.1

$\square \cdot \square \cdot \square = 27$ TASK 6b.2

$\square \cdot \square : \square = 4$ TASK 6b.3

Fullfør regnestykkene.

Tallene skal bare brukes én gang i løpet av hvert regnestykke. En kan eksempelvis ikke ha 2·2 i første regnestykke, men en kan bruke 2 én gang i alle tre regnestykker.

0	1	2	3	4	5	6	7	8	9

$7 \cdot 7 - \square - \square = 33$ TASK 6c.1

$8 \cdot 8 - \square \cdot \square = 60$ TASK 6c.2

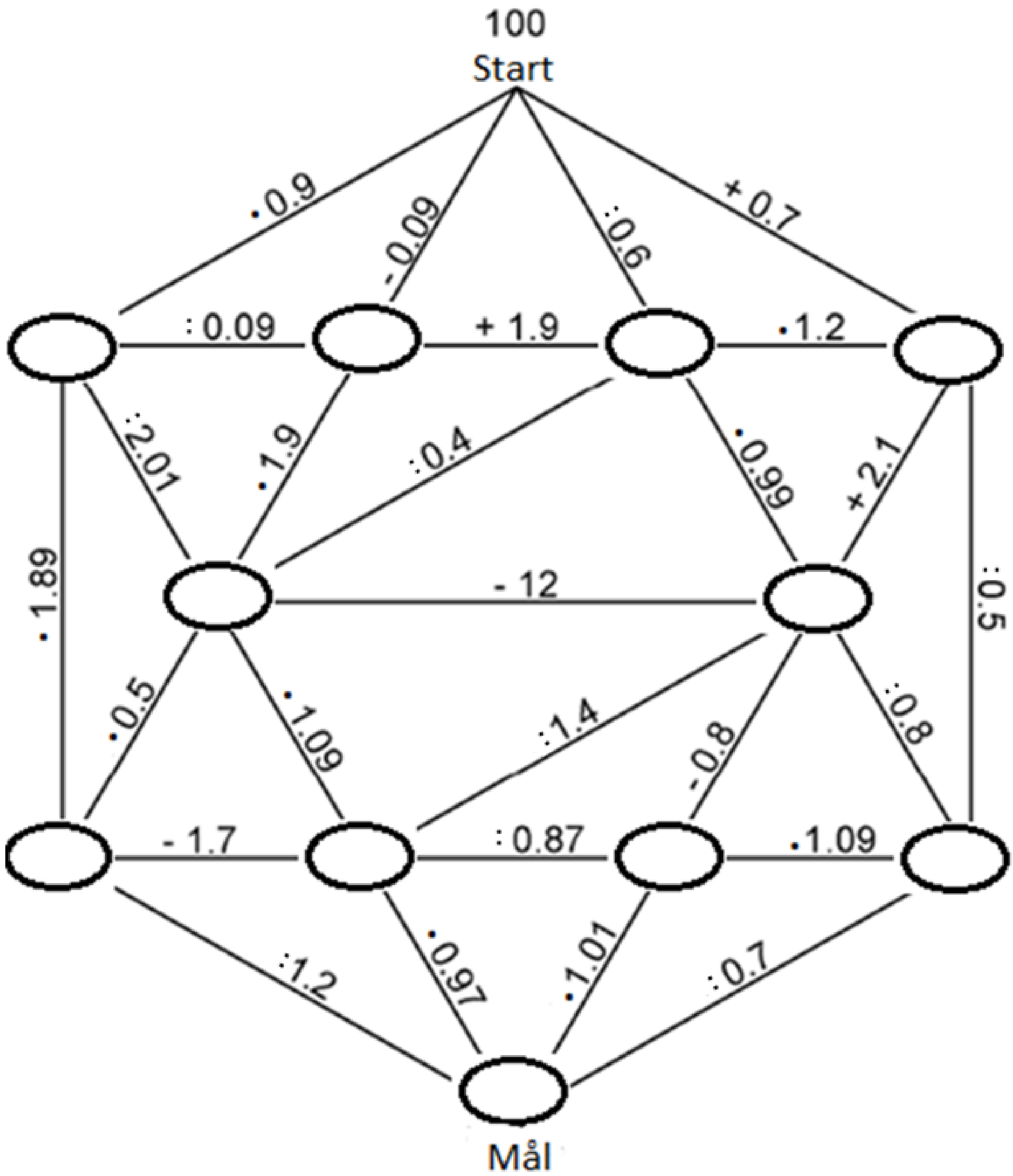
$9 \cdot 9 - \square \cdot \square = 72$ TASK 6c.3

8.8 --------Del 2 ---------

8.9 Oppgave 1 – Desimallabyrint

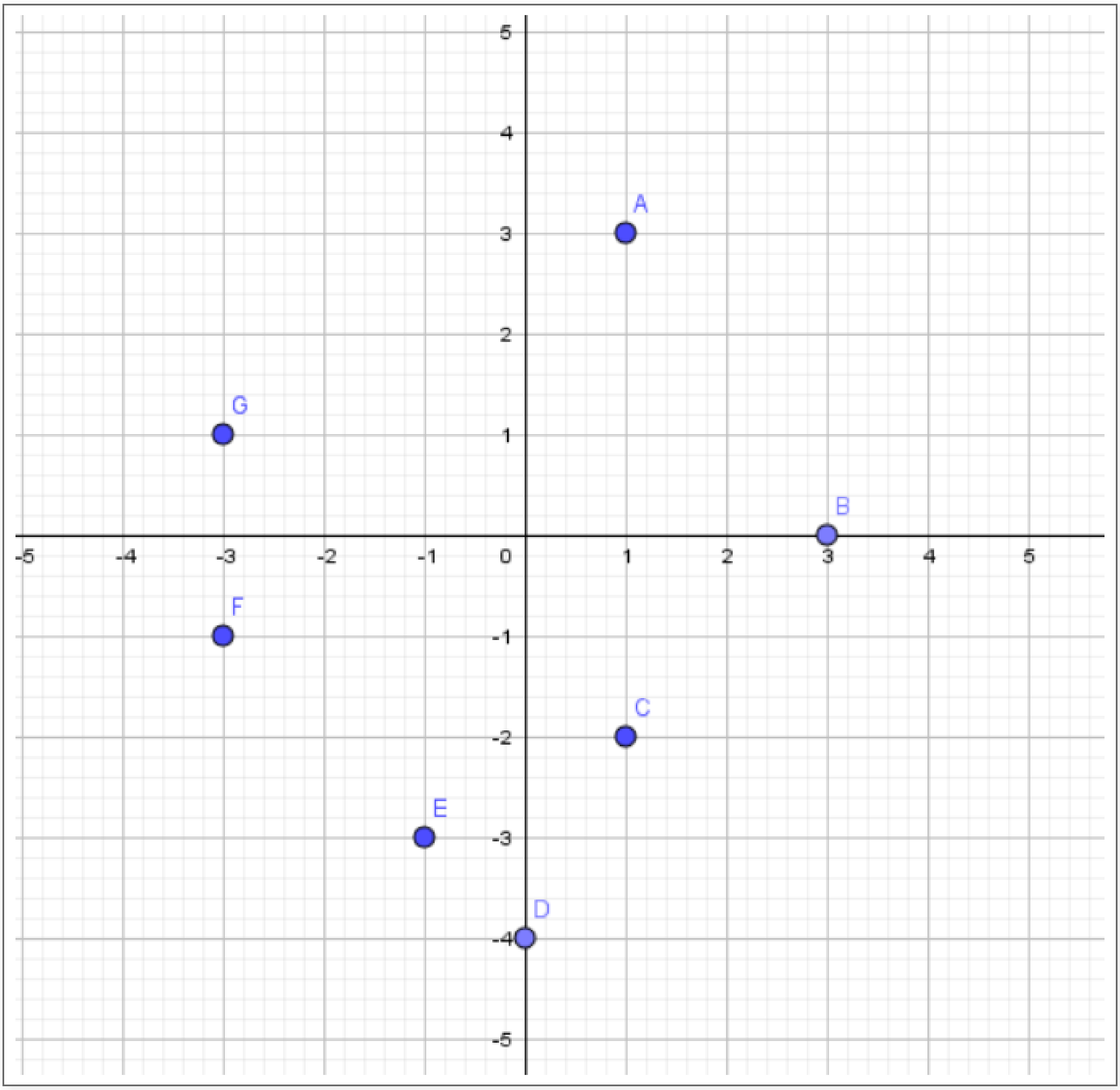
TASK 1

Beveg deg ned eller sidelengs (aldri opp) gjennom labyrinten fra start til slutt. Tegn gjerne inn streker for å vise hvilken vei du har gått. Du skal utføre regneoperasjonene og skrive svarene du kommer til underveis i feltene langs veien du velger. Du kan gjerne ta i bruk kalkulator.
Husk at du ikke kan gå oppover eller tilbake der du kom fra.
Du skal starte med en verdi på 100 på kalkulatoren. Målet ditt er å velge en vei som resulterer i størst verdi når du er ferdig. Du kan også benytte deg av kladdeark på neste side for å vise en eventuell utregning og svarene dine underveis.



8.10 Oppgave 2 – Coordinate system

Finn koordinatene



Oppgave A) - Finn Koordinatene

TASK 2A

Skriv inn riktig koordinat for de ulike punktene i koordinatsystemet på forrige side.

A: (1, 3)

B: ______________ E: ______________

C: ______________ F: ______________

D: ______________ G: ______________

Oppgave B)

TASK 2B

Tegn inn disse koordinatene i koordinatsystemet på forrige side.

H $(-3, -2)$ I $(2, -2)$ J $(2, 2)$ K $(-3, 2)$

Hva slags firkant får du hvis du trekker opp linjestykkene HI, IJ, JK og KH?

TASK 2C

Svar: ____

8.11 Oppgave 3 – Number lines

Hva blir de tre neste tallene i følgende tallrekker:

1)	0	1	2	3	4	5	6	
2)	90	100	110	120				TASK 3.2
3)	40	45	50	55				TASK 3.3
4)	43	45	47	49				TASK 3.4
5)	4	5	7	10				TASK 3.5
6)	2	2	4	6				TASK 3.6
7)	15	30	60	120				TASK 3.7
8)	4,5	4,6	4,7	4,8				TASK 3.8
9)	6,5	8	9,5	11				TASK 3.9
10)	6,5	8,5	10,5	12,5				TASK 3.10
11)	3,5	3,55	3,6	3,65				TASK 3.11
12)	6,2	12,4	24,8	49,6				TASK 3.12
13)	4	2	1	0,5				TASK 3.13
14)	9,5	9,5	19	28,5				TASK 3.14