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MODELANDO O XADREZ POR MEIO DA ANÁLISE COMBINATÓRIA E DA PROBABILIDADE: UM ESTUDO APLICADO EM UMA ESCOLA PÚBLICA DO MARANHÃO

MODELING CHESS THROUGH COMBINATORICS AND PROBABILITY: AN APPLIED STUDY IN A PUBLIC SCHOOL IN MARANHÃO

MODELANDO EL AJEDREZ MEDIANTE EL ANÁLISIS COMBINATORIO Y LA PROBABILIDAD: UN ESTUDIO APLICADO EN UNA ESCUELA PÚBLICA DE MARANHÃO

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Resumo

Este artigo apresenta os resultados de uma intervenção didático-pedagógica que articulou conceitos de Análise Combinatória e Probabilidade ao jogo de xadrez, com o objetivo de analisar o potencial dessa proposta para favorecer o desempenho dos estudantes em tarefas combinatórias e probabilísticas e em situações de resolução de problemas matemáticos em uma turma do 2º ano do ensino médio de uma escola pública maranhense. A pesquisa adotou abordagem mista, com ênfase em pesquisa-ação, e foi organizada em 12 encontros: avaliação diagnóstica; oficinas de produção do material didático (peças impressas em 3D e tabuleiro 8×8 confeccionado em banner reutilizado com velcro); oficina de xadrez em três encontros (história, regras, notação, estratégia e tática); aplicação de atividades matemáticas contextualizadas e avaliação final. Os dados foram produzidos por instrumentos de desempenho (atividades e questionários) e por registros qualitativos (diário de campo e falas). Na avaliação diagnóstica, observou-se heterogeneidade de desempenho, com 30% dos estudantes acertando apenas 1 das 8 questões de conteúdo e 12,5% alcançando 8 acertos. Após a intervenção, os percentuais de acerto nas atividades matemáticas foram predominantemente elevados em itens de contagem e probabilidade básica (≥80%), com dificuldades concentradas em itens de maior formalização, especialmente em situações de seleção sem reposição, esperança matemática e distribuição binomial. No questionário final, os itens de conteúdo apresentaram percentuais majoritariamente acima de 65%, com destaque para um item com 100% de acertos, e os itens perceptivos indicaram elevada aceitação da proposta (92,5% relataram ter gostado das atividades). Conclui-se que o xadrez, enquanto contexto de tomada de decisão e modelagem de situações, mostrou-se um recurso pedagógico promissor para tornar o estudo da contagem e da probabilidade mais significativo, desde que acompanhado de mediação didática para a passagem do intuitivo ao formal. Contudo, os resultados devem ser interpretados como evidências de associação contextual entre a intervenção e a melhora observada, e não como prova causal robusta.

Palavras-chave: Xadrez; Análise combinatória; Probabilidade; Pesquisa-ação; Ensino de Matemática.

Abstract

This article presents the results of a didactic-pedagogical intervention that articulated concepts of Combinatorics and Probability with the game of chess, aiming to analyze the potential of this proposal to improve students' performance in combinatorial and probabilistic tasks, as well as in mathematical problem-solving situations, in a second-year high school class at a public school in the state of Maranhão, Brazil. The research adopted a mixed-methods approach, with emphasis on action research, and was organized into 12 meetings: diagnostic assessment; workshops for the production of teaching materials (3D-printed pieces and an 8×8 chessboard made from reused banner material with Velcro); a chess workshop developed over three meetings (history, rules, notation, strategy, and

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tactics); the application of contextualized mathematical activities; and a final assessment. Data were produced through performance instruments (activities and questionnaires) and qualitative records (field diary and participants' statements). In the diagnostic assessment, heterogeneity in performance was observed, with 30% of the students answering correctly only 1 out of the 8 content questions and 12.5% achieving 8 correct answers. After the intervention, the percentages of correct answers in the mathematical activities were predominantly high in counting and basic probability items (≥80%), while difficulties were concentrated in items requiring greater formalization, especially in situations involving selection without replacement, expected value, and binomial distribution. In the final questionnaire, the content items showed percentages of correct answers mostly above 65%, with one item reaching 100% accuracy, and the perceptual items indicated a high level of acceptance of the proposal (92.5% reported that they enjoyed the activities). It is concluded that chess, as a context for decision-making and the modeling of situations, proved to be a promising pedagogical resource for making the study of counting and probability more meaningful, provided that it is accompanied by didactic mediation to support the transition from intuitive understanding to formal reasoning. However, the results should be interpreted as evidence of a contextual association between the intervention and the observed improvement, rather than as robust causal proof.

Keywords: Chess; Combinatorics; Probability; Action research; Mathematics Education.

Resumen

Este artículo presenta los resultados de una intervención didáctico-pedagógica que articuló conceptos de Análisis Combinatorio y Probabilidad con el juego de ajedrez, con el objetivo de analizar el potencial de esta propuesta para favorecer el desempeño de los estudiantes en tareas combinatorias y probabilísticas y en situaciones de resolución de problemas matemáticos en un grupo de 2.º año de enseñanza media de una escuela pública del estado de Maranhão, Brasil. La investigación adoptó un enfoque mixto, con énfasis en la investigación-acción, y se organizó en 12 encuentros: evaluación diagnóstica; talleres de producción del material didáctico (piezas impresas en 3D y un tablero de 8×8 confeccionado con lona reutilizada y velcro); taller de ajedrez desarrollado en tres encuentros (historia, reglas, notación, estrategia y táctica); aplicación de actividades matemáticas contextualizadas; y evaluación final. Los datos fueron producidos mediante instrumentos de desempeño (actividades y cuestionarios) y registros cualitativos (diario de campo y declaraciones de los participantes). En la evaluación diagnóstica, se observó heterogeneidad en el desempeño, con un 30% de los estudiantes acertando solamente 1 de las 8 preguntas de contenido y un 12,5% alcanzando 8 aciertos. Después de la intervención, los porcentajes de acierto en las actividades matemáticas fueron predominantemente altos en los ítems de conteo y probabilidad básica (≥80%), mientras que las dificultades se concentraron en los ítems de mayor formalización, especialmente en situaciones de selección sin reemplazo, esperanza matemática y distribución binomial. En el cuestionario final, los ítems de contenido presentaron porcentajes de acierto mayoritariamente superiores al 65%, con

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destaque para un ítem con 100% de aciertos, y los ítems perceptivos indicaron una elevada aceptación de la propuesta (el 92,5% afirmó que le gustaron las actividades). Se concluye que el ajedrez, como contexto de toma de decisiones y modelización de situaciones, se mostró como un recurso pedagógico prometedor para hacer más significativo el estudio del conteo y de la probabilidad, siempre que esté acompañado de mediación didáctica para favorecer el paso de lo intuitivo a lo formal. No obstante, los resultados deben interpretarse como evidencias de una asociación contextual entre la intervención y la mejora observada, y no como prueba causal robusta.

Palabras clave: Ajedrez; Análisis combinatorio; Probabilidad; Investigación-acción; Educación matemática.

1. Introduction

In high school, the topics of Combinatorics and Probability are often presented in a procedural manner, with an emphasis on the application of formulas and repetitive exercises. This approach may reduce learning to memorization and hinder students' understanding of what is being counted, the delimitation of the sample space, and the justification of counting strategies and probabilistic calculations. Recent reviews point to persistent difficulties in mathematics learning and advocate approaches that value investigation, argumentation, and problem solving in meaningful contexts (Lira et al., 2024; Lós & Gusmão, 2025).

In this sense, chess may be understood as a system of rules and decisions on a finite board whose dynamics naturally involve counting possibilities, case analysis, strategy selection, and risk assessment. Literature syntheses report positive effects of chess instruction on cognitive skills and academic performance, although with varying magnitude and depending on the instructional design and pedagogical mediation (Rosa et al., 2020; Sala & Gobet, 2016). Thus, rather than assuming an automatic effect, it is important to investigate how chess can function as a context for mathematical modeling and problematization, fostering the transition from intuitive understanding to formal reasoning (Sala & Gobet, 2017)..

The aim of this study was to investigate and implement a didactic-pedagogical proposal grounded in concepts of Combinatorics and Probability,

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articulated with the game of chess, in a public school in the state of Maranhão, analyzing its potential to enhance students' performance in combinatorial and probabilistic tasks as well as in mathematical problem-solving situations. The guiding hypothesis was that the logical and strategic properties of chess could promote improvements in such performance, provided that they were associated with explicit pedagogical mediation and processes of progressive formalization. This article presents the design of the intervention and discusses the quantitative and qualitative results obtained throughout the process.

The relevance of this articulation is also justified by the structuring role of combinatorics and probability in contemporary scientific education, since these fields underpin notions of uncertainty, variability, prediction, and informed decision-making, which are present both in everyday situations and in technological and scientific applications. In the school context, however, students often treat random events and counting processes as mere "intuitions," detached from systematic criteria, which increases typical errors—such as double counting, omission of cases, and inappropriate model selection—and hinders mathematical argumentation when dealing with non-routine problems.

From a didactic perspective, the choice of chess as a context is not limited to its playful appeal; rather, it is a cultural artifact with strong potential for exploring regularities and constraints (legal moves, blockages, captures, and conditions of threat to the king). It allows for the construction of finite and comparable sample spaces and also fosters discussion of enumeration strategies, such as systematic listing, possibility trees, the multiplication principle, and permutations under constraints. Situations such as "how many legal moves are possible," "which sequences lead to a given outcome," or "what is the probability of an event occurring under certain choices" make it possible to move from concrete representation (board and pieces) to symbolic formalization, with emphasis on making assumptions explicit and validating procedures.

Moreover, by requiring the anticipation of consequences and the assessment of risks, the game creates conditions for working with probabilistic concepts without reducing them to the mere application of formulas. The analysis of

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possible lines, the comparison of alternatives, and decision-making under uncertainty—for example, choosing between simplifying the position or pursuing a tactical advantage—can be didactically explored to discuss events, dependence/independence, estimates, and the interpretation of results, especially when pedagogical mediation encourages students to justify their choices, make their criteria explicit, and confront different solutions in a collaborative environment.

Finally, by adopting an intervention organized into sequential sessions, with diagnostic, monitoring, and assessment instruments, the study sought not only to measure performance but also to understand learning processes: how students describe what they are counting, which representations they mobilize, where impasses arise, and which resources—both material and discursive—support the transition from "counting by trial and error" to more robust combinatorial and probabilistic procedures. In this regard, action research makes it possible for planning, implementation, and didactic reflection to continually inform one another, producing evidence that is useful both for academic analysis and for the improvement of teaching practices in public-school contexts.

2. Literature Review

The literature in Mathematics Education has highlighted, on the one hand, the persistence of difficulties in learning mathematical content at different levels of schooling and, on the other, the need for pedagogical practices that connect conceptual knowledge with situations involving inquiry and decision-making (Lira et al., 2024). In particular, research has shown that learning becomes fragile when instruction privileges the execution of procedures without making explicit the meanings, justifications, and conditions for the use of methods. Under such circumstances, students may even arrive at correct answers in routine tasks, yet still experience difficulties when faced with problems involving constraints, multiple steps, or the need for argumentation, which is especially relevant in topics such as counting and probability.

In the specific case of Combinatorics, reviews have identified recurring gaps

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in the organization of cases, interpretation of problem statements, and selection of counting techniques, especially when instruction is limited to identifying the type of problem in order to apply a formula (Lós & Gusmão, 2025; Silva et al., 2024). A recurrent finding is the difficulty in determining what constitutes a distinct possibility, leading to errors such as double counting, omission of cases, and inconsistencies in the construction of lists and diagrams. Moreover, when the focus falls solely on arrangements, combinations, and permutations as labels, there is a tendency to reduce the problem to a superficial decision—"is it a combination or an arrangement?"—thereby shifting attention away from the conditions and constraints of the context, the underlying assumptions, and the multiplicative reasoning involved.

The literature also indicates that intermediate representations—such as systematic listings, tables, possibility trees, Venn diagrams, and step-by-step counting schemes—are decisive in supporting the transition from intuitive reasoning to formalization. In this sense, problem-oriented instruction, with emphasis on the explicit presentation of procedures and the validation of results, tends to foster the understanding of principles such as the multiplication principle, the addition principle, and the use of complements (Silva et al., 2024). These findings reinforce that, more than memorizing formulas, students need to develop criteria for decomposing situations, organizing cases, and justifying why a given counting strategy is appropriate.

As for Probability, studies examining teaching materials and school practices indicate challenges related to the construction of the sample space, the distinction between dependent and independent events, and the interpretation of fractional and percentage representations (Silva & Guimarães, 2024). Frequent difficulties include: (i) confusion between possibility and probability; (ii) inadequate understanding of ratios and proportions; (iii) unwarranted generalizations based on a small number of cases; and (iv) a limited interpretation of chance as a matter of opinion or personal belief, detached from modeling. Furthermore, when probability is taught merely as the calculation of fractions of favorable cases over possible cases, assumptions such as equiprobability and independence may become naturalized, even though they are not always valid, thereby impairing critical reasoning in more realistic situations.

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Within this context, games and playful activities have been proposed as resources for promoting engagement, mathematical communication, and the development of problem-solving heuristics (Pereira, 2025). However, the literature emphasizes that the educational potential of games is not automatic: learning depends on explicit objectives, well-defined mathematical tasks, and teacher mediation capable of transforming in-game actions into objects of reflection. In other words, playfulness may foster participation, but conceptual understanding requires interventions that encourage students to explain procedures, compare strategies, justify results, and generalize patterns.

Chess, in particular, stands out as a game of perfect information that engages planning, anticipation of consequences, working memory, and self-control. From an educational perspective, the game offers an environment with clear rules, well-defined constraints, and a finite space of possibilities, which is especially fertile for discussions of counting and modeling: legal moves, captures, threats to the king, sequences of moves, and possible board configurations constitute situations in which students can enumerate cases, establish criteria for distinction, and construct sample spaces based on verifiable assumptions. Thus, chess can function as a laboratory for exploring regularities and constraints, bringing combinatorial reasoning closer to concrete contexts.

Reviews and meta-analyses report small to moderate positive effects of chess programs on cognitive skills and academic achievement, highlighting the importance of structured interventions explicitly connected to curricular objectives (Rosa et al., 2020; Sala & Gobet, 2016). These studies also draw attention to the heterogeneity of the results: impacts vary according to program duration, student profile, mediator training, and, above all, the degree of integration between chess and school content. In particular, the literature suggests that interventions focused exclusively on learning how to play tend to produce more limited effects than proposals that incorporate mathematical tasks, guided discussions, and monitoring instruments.

Experimental studies with active control groups also suggest gains in mathematical problem-solving when chess instruction is intentionally integrated with

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mathematical tasks (Sala & Gobet, 2017). From this perspective, chess does not appear as a general solution, but rather as a context for developing cognitive and metacognitive skills—such as planning, monitoring, and evaluating strategies—that can be mobilized in problem solving. At the same time, research warns that transfer to mathematical performance tends to be greater when students are encouraged to recognize correspondences between decisions made in the game and decisions required in problem situations—for example, identifying constraints, comparing alternatives, and justifying choices.

According to national curricular guidelines, which emphasize competencies related to problem solving, argumentation, and decision-making (BRASIL, 2018), this study adopts chess as a context for modeling: a setting in which students can represent situations, enumerate possibilities, justify strategies, and assess probabilistic risks based on board configurations. Within this framework, modeling takes shape when students transform a game situation into a mathematical question, explain their assumptions (for example, which moves are to be considered and under what constraints), choose representations (such as listings, trees, or tables), and validate results, thereby connecting "acting on the board" with "explaining in mathematical language."

Some studies have also explored the articulation between chess and probability/statistics in didactic proposals (Viana, 2020; Castilho, 2020). In general, these initiatives value typical game situations—such as sequences of moves, attack/defense patterns, and the comparison of alternatives—as a starting point for constructing notions of sample space, events, and estimates. In summary, the literature converges in advocating proposals in which chess is used not merely as a motivational tool, but as an environment for problematization and formalization, requiring careful pedagogical mediation so that learning in Combinatorics and Probability may be consolidated in a meaningful way.

3. Methodology

The study was conducted in a public school in the state of Maranhão, located in an inland municipality, with a second-year high school class. A total of 40 students

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participated from beginning to end of the process, which made it possible to monitor the group's development throughout the entire intervention.

A mixed-methods approach (quantitative and qualitative) was adopted, with an emphasis on action research, integrating pedagogical intervention, systematic data production, and reflection on teaching practice.

This framework was chosen because it made it possible to: (i) plan, implement, and adjust didactic actions based on evidence collected throughout the process; and (ii) understand not only performance outcomes, but also learning processes, the strategies adopted by the students, and forms of participation.

The design of the intervention followed a conceptual progression and a process of familiarization with the chess context, seeking to reduce novelty effects and ensure minimum conditions for participation.

Accordingly, the activities were organized so that students could move from concrete actions on the board (moves, constraints, and decision-making) to intermediate representations (listings, tables, and possibility trees) and, finally, to more formalized procedures in counting and probability.

Teacher mediation prioritized the explicit statement of assumptions, the justification of strategies, and the validation of results through the comparison of solutions, with moments of collaborative work and whole-class discussion.

Data production drew on multiple sources, triangulating performance instruments and qualitative records: (i) a diagnostic assessment (pre-intervention), composed of items on student profile and prior contact with chess, as well as content questions in Combinatorics and Probability; (ii) activity sheets administered throughout the sessions, in both individual and group formats, with records of item-level accuracy and observation of procedures (for example, case organization, justifications, and use of representations); (iii) a short test at the end of the chess workshop, focusing on moves, essential rules, and recognition of constraints (move legality), in order to ensure that later difficulties would not be attributed exclusively to lack of knowledge of the game; (iv) a final questionnaire containing perceptual items (engagement, interest, self-assessment, and acceptance of the proposal) and content items (application of counting principles and probabilistic notions in

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contextualized situations); and (v) qualitative records, including field notes, students' written productions, and brief statements collected during discussions and sharing sessions.

As for the treatment of quantitative data, a descriptive analysis was carried out using absolute frequencies and percentages of correct answers per item, comparing trends between the diagnostic assessment and the post-intervention stage whenever applicable.

To strengthen the analytical consistency of the study, a formal comparison was also conducted between the diagnostic assessment and the final questionnaire, considering the same 40 students who responded to both instruments. Since the instruments contained different numbers of content items—8 in the diagnostic assessment and 10 in the final questionnaire—the comparison was based on the individual proportion of correct answers in each instrument, rather than solely on the raw total of correct responses.

In addition to frequencies and percentages of correct answers by item, the mean, standard deviation, median, and absolute gain in percentage points were calculated. Relative gain and normalized gain, $g = \frac{pós - pré}{1 - pré}$, were also estimated, as well as a simple effect-size measure, namely the paired effect size d_z, obtained by dividing the mean of the individual differences by the standard deviation of those differences. To assess the difference between the two moments, the Wilcoxon signed-rank test for paired samples was used, adopting a significance level of 5%.

Both the diagnostic assessment and the final questionnaire were completed individually, without consultation of supporting materials, and each lasted two hours. There were no sample losses and no unanswered items. Although the instruments were not identical, an effort was made to maintain a comparable level of difficulty between the diagnostic assessment and the final questionnaire, so as to enable a pedagogically meaningful comparison of performance throughout the intervention.

Considering the action-research nature of the study, the absence of a comparison group, and the contextualized character of the tasks, the quantitative results were interpreted as evidence of a contextual association between the intervention and the observed performance, rather than as a robust demonstration

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of causality.

In successive activity items, the analysis considered both the pattern of correct responses and the recurrence of typical errors—such as double counting, omission of cases, unwarranted assumptions of equiprobability, and confusion between possibility and probability—as a way of identifying points of greater conceptual demand.

The qualitative data were organized into analytical categories related to (a) engagement and participation (initiative, collaboration, and persistence), (b) self-control and behavioral regulation (respect for turn-taking, attention to rules, and the ability to revise strategies), and (c) perceptions of learning (perceived clarity, reported difficulties, and the usefulness attributed to chess as a context), thereby allowing the numerical results to be interpreted in light of the interactions and strategies mobilized during the tasks.

The didactic sequence comprised 12 sessions, planned in an integrated manner: an initial diagnostic assessment; preparatory workshops for the production of didactic materials; leveling and consolidation of fundamental chess concepts; implementation of contextualized mathematical activities in Combinatorics and Probability; and final consolidation and assessment.

Table 1 presents a structured synthesis of the didactic-pedagogical sequence developed over the course of 12 sessions, explaining the progressive organization of the intervention from the initial diagnostic assessment to the final evaluation. This synthesis makes it possible to visualize the logic underlying the sequence of stages, highlighting how the proposal articulated the use of chess as a modeling context, teacher mediation, and the instruments used to monitor students' performance and perceptions.

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Table 1: Summary of the Sequence of Sessions

Session	Stage/Activity	Pedagogical Focus
1	Diagnostic Assessment	Baseline assessment (student profile, counting and probability)
2	Workshop (Part 1): 3D Modeling and Printing	Authorship and collaboration in the production of the pieces
3	Workshop (Part 2): 8x8 Board and Velcro	Construction of the manipulative material
4	Chess Workshop (Part 1/3)	Origins, history and contextualization
5	Chess Workshop (Parte 2/3)	Rules, moves, Algebraic Notation and phases of the game
6	Chess Workshop (Parte 3/3)	Strategy, tactis and special rules
7	Activity 2 (Group Work)	Introduction to Combinatorics through Chess
8	Activity 3 (Individual Work)	Introduction to Probability Chess
9	Activity 4 (Group Work)	Tactical strategies and probabilistic reasoning
10	Activity 5 (Group Work)	Chessboard practice and performance recording
11	Consolidation	Pedagogical feedback and discussion of strategies
12	Final Questionnaire and Culminating Activity (Chess Tournament)	Perceptions and content; culminating activity (Chess Tournament)

Source: Prepared by the authors (2026).

The production workshops involved the modeling/design and 3D printing of chess pieces, as well as the construction of an 8×8 board using a reused banner, with 32 white squares measuring 10 cm and Velcro attached both to the squares and to the pieces, as shown in Figure 1. This physical resource facilitated manipulation, piece fixation, and the simulation of specific configurations during the activities, reducing ambiguities regarding positions and moves and supporting the transition from the concrete to counting representations — for example, enumerating legal moves from a previously assembled position.

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Figure 1: Board construction stage



Source: Prepared by the authors (2026).

The chess workshop (Figure 2) was distributed across three sessions and included historical and cultural elements of the game, as well as, above all, rules, notation, and basic principles of strategy and tactics, so as to ensure that students were able to operate with the board as a rule-based system.

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Figure 2: Chess Workshop



Source: Prepared by the authors (2026).

In the mathematical activities stage, the problems were selected and/or adapted to explore, in a progressive manner, counting strategies (the multiplication and addition principles, systematic enumeration, and constraints) as well as basic probabilistic concepts (sample space, events, interpretation of percentages, and comparison of chances), including more formal items such as selection without replacement, expected value, and the binomial distribution, in order to map limits and the need for additional mediation. Figure 3 presents the responses of 5 out of the 8 groups to the eight queens problem, illustrating different strategies for organizing cases and searching for solutions. Throughout the process, moments of synthesis and institutionalization of learning were planned, with the recording of procedures and the discussion of common errors as opportunities for learning.

Figure 3: Responses from 5 groups to the Eight Queens Problems



Source: Prepared by the authors (2026).

Regarding ethical aspects, the research followed procedures of informed consent and assent, in addition to measures to ensure the anonymization of both participants and the institution. In order to preserve the institution's identity and

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guarantee confidentiality, the article does not mention the name of the school and uses generic references to the context in which the study was conducted. The data presented are aggregated and do not allow for the individual identification of students, in accordance with the guidelines of the ethics committee and with good practices in research involving human participants.

4. Results and Discussion

At the diagnostic stage, as shown in Table 2—Initial indicators and post-chess workshop results (p. 17)—half of the students (50%) reported having never had any contact with chess, and 67.5% stated that they did not know the game; moreover, no students classified themselves as intermediate or advanced players, indicating the need for prior leveling. In terms of performance, the distribution of correct answers across the eight content questions (0 to 8) revealed marked heterogeneity: 30% obtained only 1 correct answer (12 students), whereas 12.5% obtained 8 correct answers (5 students).

Considering the same 40 students at both time points, the formal comparison between the diagnostic assessment and the final questionnaire showed a consistent improvement in performance. In raw terms, the mean increased from 3.25 correct answers out of 8 items (SD = 2.50) in the diagnostic assessment to 7.60 correct answers out of 10 items (SD = 1.88) in the final questionnaire. Since the instruments had different lengths, the main comparison was carried out using the individual proportion of correct answers: the standardized mean increased from 40.63% to 76.00%, with a mean absolute gain of 35.38 percentage points. The relative gain was 87.1%, and the mean normalized gain was g = 0,596.

The Wilcoxon signed-rank test for paired samples indicated a statistically significant difference between the two time points ($p < 0,001$), and the paired effect size was $d_z = 0,98$, suggesting a large magnitude across the set of assessed tasks. Even so, this result should be interpreted with caution: since this was an intervention without a comparison group, carried out in a single class and with tasks directly related to the content addressed, the findings support an improvement in performance associated with the didactic sequence, but do not warrant robust causal

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inference or evidence of broad transfer.

This interpretive caution is consistent with the literature discussing the effects of chess on learning and transfer, according to which the magnitude of results depends on the design of the intervention, the pedagogical mediation, and the type of outcome assessed. In the present study, the focus was placed on performance in directly taught and contextualized tasks, which tends to favor more localized gains.

Table 2: Initial Indicators and Post-Chess Workshop Results

Indicator	Category / Item	Frequency	Percentage
Correct answers in the diagnostic assessment (0-8)	0 correct answers	1	2,5%
Correct answers in the diagnostic assessment (0-8)	1 correct answer	12	30%
Correct answers in the diagnostic assessment (0-8)	2 correct answers	7	17,5%
Correct answers in the diagnostic assessment (0-8)	3 correct answers	7	17,5%
Correct answers in the diagnostic assessment (0-8)	4 correct answers	3	7,5%
Correct answers in the diagnostic assessment (0-8)	5 correct answers	1	2,5%
Correct answers in the diagnostic assessment (0-8)	6 correct answers	2	5%
Correct answers in the diagnostic assessment (0-8)	7 correct answers	2	5%
Correct answers in the diagnostic assessment (0-8)	8 correct answers	5	12,5%
Post-Workshop Short Test	Bishop's Move	32/40	80%
Post-Workshop Short	Knight's Move	24/40	60%

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Test			
Post-Workshop Short Test	Castling	36/40	90%
Post-Workshop Short Test	Pawn Promotion	40/40	100%
Post-Workshop Short Test	Identifying Check	36/40	90%

Source: Prepared by the authors (2026).

The results of the short test administered after the workshop indicated consolidation of essential rules, especially in items related to castling, promotion, and identifying check, although the knight's move remained the most difficult item (60%). The workshop and leveling stage proved to be relevant for enabling the subsequent mathematical activities, reducing noise arising from unfamiliarity with the game.

In Activity 2 (Introduction to Combinatorics through Chess), most items showed correctness rates between 50% and 100%, suggesting that counting possibilities in board-based contexts supported the organization of cases and the discussion of strategies. However, one item that required careful reading of the constraints associated with legal moves showed low performance (12.5%), indicating that difficulties in interpretation and modeling may persist even when the context is motivating. In one of the classical problems addressed, concerning the placement of eight queens on a chessboard, five groups arrived at the complete solution, as shown in Figure 3, recognizing the existence of 92 valid arrangements.

In Activity 3 (Introduction to Probability through Chess), high performance was observed in items 1 to 8, with percentages ranging from 80% to 100%, indicating that most students were able to structure events, construct sample spaces, and apply calculation procedures in direct and moderately complex situations. A sharp decline was concentrated in items 9 (2.5%) and 10 (0%), which required more formal probabilistic modeling.

The full statement of item 9 was as follows: "From a set of 10 pieces used to set up an exercise (2 queens, 3 rooks, 2 bishops, 2 knights, and 1 king), 4 pieces are randomly selected without replacement to construct a position. (a) What is the probability that exactly 1 of the selected pieces is a queen? (b) What is the probability

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that no queen is selected?" The low performance suggests difficulty in correctly organizing the sample space and in articulating combinatorial counting with probabilistic calculation in a non-elementary situation. In this case, the obstacle appears to have been less the chess context itself and more the need to recognize that the situation required modeling a selection without replacement, with simultaneous control of both the total number of cases and the favorable cases.

Item 10 required an even greater degree of formalization. Its full statement was as follows: "Imagine that, in a simplified mini-tournament, each player makes 3 moves. On each move, the probability of achieving a capture is 0.2 (independent across moves). (a) What is the mathematical expectation (expected value) of the number of captures in 3 moves? (b) What is the probability that the player makes exactly 2 captures in 3 moves? (Use the binomial distribution.)" The absence of correct responses on this item indicates that the main difficulty was not merely a computational error, but rather the recognition of the appropriate mathematical model and the distinction between two conceptually different demands: expected value and binomial point probability.

In pedagogical terms, these results show that students were better able to work with direct probabilities and more immediate contexts than with situations requiring explicit formalization, parameterization, and the use of specific expressions. This is consistent with the literature on recurring difficulties in Probability, especially when students must decide which model to apply, manage constraints, and justify why a given formulation is appropriate.

After the guided correction of this activity, with conceptual review and explicit discussion of the expressions involved, evidence of subsequent learning was observed in the final questionnaire. Items related to probability without replacement and binomial modeling showed percentages higher than those found in Activity 3, suggesting that the main barrier lay in the students' initial unfamiliarity with these formalisms, rather than in any inability to learn the content itself..

In Activities 4 (Tactical Strategies and Probabilistic Reasoning) and 5 (Chessboard Practice and Performance Recording), which integrated board reading, decision-making, and probabilistic reasoning in tactical scenarios, performance

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remained high on most items, with occasional declines in situations requiring more refined inference and comparison of alternatives. In the final questionnaire, composed of 15 questions—5 perceptual items (items 1 to 5) and 10 content items (items 6 to 15), as shown in Table 3—Final questionnaire: content items (6 to 15) with 40 participants (p. 20)—the content items showed percentages predominantly above 65%, with item 6 standing out at 100%, while the perceptual items indicated a high level of acceptance: 92.5% reported that they liked the activities.

Table 3: Final Questionnaire: Content Items (6 to 15) with 40 Participants

Item	Correct Answers	Percentage
6	40/40	100%
7	33/40	82,5%
8	33/40	82,5%
9	30/40	75%
10	26/40	65%
11	26/40	65%
12	27/40	67,5%
13	31/40	77,5%
14	33/40	82,5%
15	25/40	62,5%

Source: Prepared by the authors (2026).

In addition to the percentages, the qualitative records should be read as indicative and exploratory evidence of the process experienced by the students, rather than as proof of a direct relationship between engagement, self-control, and mathematical performance. Throughout the activities, statements emerged such as: “Teacher, I’m now able to think first before doing something, to decide whether it will be worth it or not”; “It seems that I can remember math formulas better now”; and “I feel more confident when I have to do a calculation on my own.” Such remarks suggest greater intentionality in decision-making, revision of strategies, and self-confidence in dealing with mathematical tasks.

However, since the study did not carry out an individual correlation between

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subjective perceptions and performance scores, these statements are interpreted only as contextual elements that help to understand the reception of the proposal and the pedagogical dynamics observed. In this way, the analysis avoids attributing the improvement in performance to engagement alone, while maintaining its primary analytical focus on the results obtained in the content-based instruments.

In summary, the set of quantitative and qualitative data supports the view that the intervention was associated with improved performance in Combinatorics and Probability tasks, especially in counting and basic probability, as well as with a broadly favorable reception of the proposal by the students. However, the absence of a comparison group, the contextualized nature of the instruments, and the fact that the study was conducted in a single class prevent these findings from being interpreted as robust causal evidence or as a demonstration of broad transfer to domains not directly addressed.

5. Conclusion

The intervention showed that chess can function as a fertile context for the modeling and solving of problems in Combinatorics and Probability, as it offers concrete situations involving the counting of possibilities, the organization of cases, and the assessment of risks within a finite space governed by clear rules.

Throughout the process, the board and the pieces operated as supports for the construction of sample spaces, the explicit identification of constraints, and the comparison of strategies, thereby fostering the transition from trial-and-error solutions to more systematic procedures (organized listings, the use of tables/possibility trees, and justifications based on counting principles). In this sense, chess proved to be a powerful means of triggering discussions about “what counts as a distinct case,” about enumeration criteria, and about how the assumptions adopted may alter the result—issues that are central to both combinatorics and probability.

The results revealed initial heterogeneity and improved performance by the end of the intervention. In the formal comparison between the diagnostic assessment and the final questionnaire, the standardized mean of correct answers increased

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from 40,63% to 76,00%, with a mean absolute gain of 35,38 percentage points, a normalized gain of $g = 0{,}596$ and a statistically significant pre-/post-intervention difference according to the Wilcoxon test ($p < 0{,}001$). The strongest results were concentrated in items involving counting and basic probability, whereas the greatest difficulties remained in tasks requiring a higher degree of formalization, such as selection without replacement, expected value, and the binomial distribution.

These findings suggest that the proposal was relevant in fostering performance in Combinatorics and Probability tasks and in expanding students' repertoire of problem-solving strategies. However, due to the absence of a control group, the focus on a single class, and the contextualized nature of the instruments, the data should not be interpreted as robust causal proof or as evidence of broad transfer to domains not directly addressed.

In didactic terms, the intervention also showed that the "closeness" of chess to students' everyday experience does not eliminate mathematical challenges; on the contrary, it makes them more visible and open to discussion, offering the teacher opportunities to intervene in relation to typical errors (omissions, double counting, assumed equiprobability, and confusion between possibility and probability) as well as incomplete arguments.

From a pedagogical perspective, the following aspects stand out: (i) the importance of leveling students' knowledge of the rules of the game so that mathematical performance is not confused with lack of familiarity with chess; (ii) the potential of low-cost manipulative materials, produced through reuse and 3D printing, to foster participation, collaboration, and clarity in simulations; and (iii) the need for explicit mediation to support the transition from intuitive reasoning to formalization, through guiding questions, collective validation of solutions, and the intentional use of intermediate representations. It was observed that mediation played a decisive role in transforming actions on the board into mathematical objects: when students were encouraged to make their assumptions explicit, justify procedures, and compare strategies, advances emerged in the quality of their reasoning and in mathematical communication.

As limitations, the absence of a control group and the implementation in a

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single class should be noted, which restrict causal inferences and broad generalizations. It is also acknowledged that part of the results may be related to contextual factors, such as group dynamics and the motivational effect of the materials produced, which reinforces the need for comparative studies.

As future directions, it is recommended that the proposal be replicated in different school contexts and grade levels, that variations in the didactic design be tested (for example, a greater number of sessions devoted to probabilistic formalization), and that long-term effects on performance, autonomy, and the transfer of strategies to problems not contextualized through chess be investigated. Finally, the experience supports the view that integrating chess, combinatorics, and probability is a promising way to make the study of counting and uncertainty more meaningful and argumentative, provided that the game is treated as a context for problematization and modeling, rather than merely as a motivational activity.

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