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EFEITO DA APRENDIZAGEM COOPERATIVA NAS DISPOSIÇÕES DE PENSAMENTO CRÍTICO EM ALUNOS DE MATEMÁTICA A

EFFECT OF COOPERATIVE LEARNING ON CRITICAL THINKING SKILLS IN MATHEMATICS A STUDENTS

EFECTO DEL APRENDIZAJE COOPERATIVO EN LAS DISPOSICIONES DE PENSAMIENTO CRÍTICO DE LOS ESTUDIANTES DE MATEMÁTICAS A

Maria Magalhães[1,2] *https://orcid.org/0009-0009-4689-5464*
Maria Helena Silva[1,2] *https://orcid.org/0000-0003-2855-9634*
José Lopes[1,2] *https://orcid.org/0000-0002-6845-8371*

[1] Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal
[2] CIIE - Centro de Investigação e Intervenção Educativas da Universidade do Porto, Porto, Portugal

Maria Magalhães – 500gmagalhaes@eshm.edu.pt| Maria Helena Silva – helsilva@utad.pt | José Lopes- jlopes@utad.pt

Corresponding Author:
Maria Magalhães
Rua do Outeiro
4705– 807 – Braga– Portugal
500gmagalhaes@eshm.edu.pt

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RESUMO

Introdução: O pensamento crítico é uma competência fundamental no ensino da Matemática, promovendo capacidades de análise, interpretação e argumentação, essenciais na resolução de problemas. Para o desenvolvimento destas capacidades, são necessárias disposições como mente aberta, procura da verdade e sistematicidade. As disposições de pensamento crítico orientam e sustentam o desenvolvimento de capacidades cognitivas, permitindo a análise e a interpretação de problemas de forma crítica e estruturada. A aprendizagem cooperativa emerge como uma abordagem pedagógica eficaz, ao fomentar a interação entre os alunos, contribuindo para o desenvolvimento de disposições de pensamento crítico. No entanto, a investigação sobre o impacto na promoção de disposições de pensamento crítico, em particular em Matemática A, em Portugal, é ainda limitada. O presente estudo visa colmatar esta lacuna, alinhando-se com o Perfil dos Alunos à Saída da Escolaridade Obrigatória e as Aprendizagens Essenciais.
Objetivo: Analisar o efeito da aprendizagem cooperativa no desenvolvimento de disposições de pensamento crítico em alunos do 11.º ano de Matemática A, comparando-a com métodos de ensino tradicionais, e verificar se existem diferenças de género nesse contexto.
Métodos: Estudo quasi-experimental, com dois grupos intactos: um grupo experimental (70 alunos), que utilizou métodos de aprendizagem cooperativa, e um grupo de controlo (49 alunos), que seguiu uma abordagem mais tradicional de ensino. A Escala de Disposições de Pensamento Crítico foi aplicada em pré e pós-teste a ambos os grupos.
Resultados: Apenas o grupo experimental apresentou melhorias estatisticamente significativas do pré para o pós-teste.
Conclusão: A aprendizagem cooperativa demonstrou ser mais eficaz do que o ensino tradicional no desenvolvimento das disposições de pensamento crítico avaliadas.

Palavras-chave: aprendizagem cooperativa; pensamento crítico; disposições; matemática A

ABSTRACT

Introduction: Critical thinking is a fundamental skill in the teaching of mathematics, promoting skills of analysis, interpretation, and argumentation, which are essential for solving problems. Developing these skills requires dispositions such as open-mindedness, truth-seeking, and systematicity. Critical thinking dispositions guide and support the development of cognitive skills, enabling the analysis and interpretation of problems in a critical and structured way. Cooperative learning emerges as a practical pedagogical approach that fosters student interaction and contributes to developing critical thinking dispositions. However, research on the impact of cooperative learning in promoting critical thinking skills, particularly in Mathematics A, in Portugal, is still limited. This study aims to fill this gap, in line with the *Profile of Students Leaving Compulsory Schooling* and *Essential Learning*.
Objective: To analyze the effect of cooperative learning on the development of critical thinking skills in 11th-grade Mathematics A students, comparing it with traditional teaching methods, and to see if gender differences exist in this context.
Methods: Quasi-experimental study, with two intact groups: an experimental group (70 students), which used cooperative learning methods, and a control group (49 students), which followed a more traditional teaching approach. The Critical Thinking Dispositions Scale was applied in pre and post-test to both groups**.**
Results: Only the experimental group showed statistically significant improvements from pre to post-test.
Conclusion: Cooperative learning proved to be more effective than traditional teaching in developing critical thinking dispositions assessed.

Keywords: cooperative learning; critical thinking; dispositions; mathematics A

RESUMEN

Introducción: El pensamiento crítico es una habilidad fundamental en la enseñanza de las matemáticas, ya que fomenta las capacidades de análisis, interpretación y argumentación, esenciales para resolver problemas. El desarrollo de estas habilidades requiere disposiciones como la apertura mental, la búsqueda de la verdad y la sistematicidad. Las disposiciones de pensamiento crítico guían y apoyan el desarrollo de las habilidades cognitivas, permitiendo analizar e interpretar los problemas de forma crítica y estructurada. El aprendizaje cooperativo surge como un enfoque pedagógico eficaz al fomentar la interacción entre los estudiantes, contribuyendo al desarrollo de las disposiciones de pensamiento crítico. Sin embargo, la investigación sobre el impacto del aprendizaje cooperativo en la promoción de las habilidades de pensamiento crítico, en particular en Matemáticas A, en Portugal, es todavía limitada. Este estudio pretende llenar este vacío, en consonancia con el Perfil de los Estudiantes que Abandonan la Enseñanza Obligatoria y los Aprendizajes Esenciales.
Objetivo: Analizar el efecto del aprendizaje cooperativo en el desarrollo de habilidades de pensamiento crítico en estudiantes de 11º curso de Matemáticas A, comparándolo con los métodos tradicionales de enseñanza, y comprobar si existen diferencias de género en este contexto.
Métodos: Estudio cuasiexperimental, con dos grupos intactos: un grupo experimental (70 estudiantes), que utilizó métodos de aprendizaje cooperativo, y un grupo de control (49 estudiantes), que siguió un enfoque de enseñanza más tradicional. La Escala de Disposiciones de Pensamiento Crítico se aplicó en pre- y post-test a ambos grupos.
Resultados: Sólo el grupo experimental mostró mejoras estadísticamente significativas entre el pre- y el post-test.
Conclusión: El aprendizaje cooperativo demostró ser más eficaz que la enseñanza tradicional en el desarrollo de disposiciones de pensamiento crítico evaluadas.

Palabras clave: aprendizaje cooperativo; pensamiento crítico; disposiciones; matemáticas A

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INTRODUCTION

Critical thinking is widely recognized as an essential competence in teaching mathematics, and it plays a crucial role in the analysis, interpretation, and resolution of complex problems (Facione, 2011; Paul & Elder, 2006). In Portugal, curricular guidelines, such as the Profile of Students Leaving Compulsory Education (Martins et al., 2017) and Essential Learning (DGE, 2018), emphasize the importance of promoting pedagogical strategies that stimulate the development of this skill to provide students with the ability to make informed decisions and solve real problems. In critical thinking, capacities and dispositions coexist as fundamental elements that complement each other in their development and application (Facione, 2011). While critical thinking skills encompass interpretation, evaluation, and argumentation, dispositions reflect the propensity to apply these skills reflexively and systematically in diverse contexts (Dwyer, 2017; Facione, 2011). Developing cognitive skills alone is insufficient to promote effective critical thinking since, without adequate dispositions, students may face difficulties using critical thinking autonomously and consistently (Facione, 2011). In this context, cooperative learning has been highlighted as a practical pedagogical approach to foster critical thinking dispositions, since its application promotes learning environments that stimulate interaction, argumentation, and the collective construction of knowledge (Loes & Pascarella, 2017).

Recent studies point to the fact that cooperative methodologies not only increase student engagement but also promote the development of dispositions such as truth-seeking, open-mindedness, and systematicity, affective components that condition the development of critical thinking skills (Erdogan, 2019; Klang et al., 2021; Lopes et al., 2021).

However, research on the impact of cooperative learning on the development of critical thinking dispositions in teaching Mathematics A in secondary school is still limited. Recent studies reveal that, despite students demonstrating a positive predisposition towards critical thinking, more traditional teaching methods are not always effective in systematically promoting it (Morais et al., 2023). Thus, it is relevant to deepen the impact of cooperative practices, analyzing to what extent they influence the development of critical thinking dispositions in the school context.

1. LITERATURE REVIEW

This section outlines the conceptual and theoretical foundations underpinning the study. It addresses the core principles of cooperative learning, its relevance to mathematics education, and its potential for fostering critical thinking dispositions. Given the increasing focus on active learning and the development of transversal competencies in contemporary curricula, it is essential to examine how structured cooperative strategies contribute to both cognitive and affective domains of student learning. The following subsections explore the pedagogical frameworks and empirical evidence that inform the present research.

1.1. Cooperative Learning: Concepts and Foundations

Cooperative learning is a pedagogical model that promotes interaction among students in small, heterogeneous groups, facilitating the collective construction of knowledge. This approach encourages argumentation, the exchange of diverse perspectives, and the synthesis of ideas, which are fundamental for critical thinking (Silva et al., 2022; Van Ryzin et al., 2020). Applied in various subjects, including Mathematics, it has demonstrated effectiveness in developing higher cognitive skills (Loes & Pascarella, 2017; Sutana et al., 2022).

The teacher plays a crucial role in structuring activities that foster debate and joint analysis of solutions (Lopes et al., 2020). Cooperative groups are distinguished by five key elements (Figure 1): positive interdependence, individual and group accountability, face-to-face promotive interaction, group evaluation, and social skills and group processing (Silva et al., 2022).

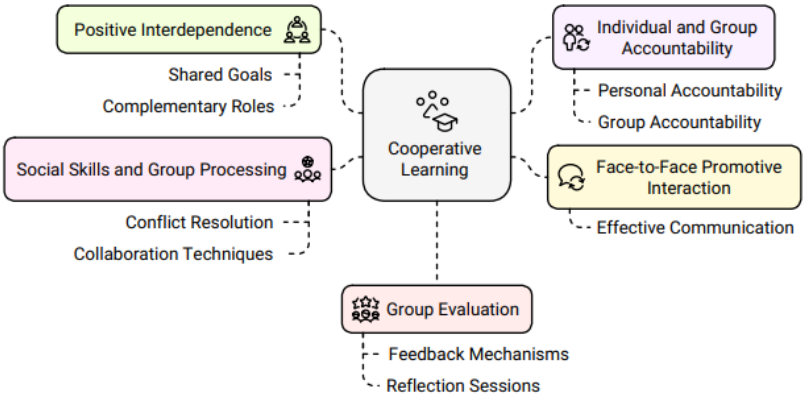

Figure 1 – Essential elements of cooperative learning

Source: Infographic created in Napkin with data from the author

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Cooperative learning can be implemented using methods such as Student Teams—Achievement Divisions (STAD), where students work in teams to understand the content and improve performance in individual assessments, promoting positive interdependence and collective responsibility; Think-Pair-Share which enables divergent thinking through verbalization of strategies used in problem-solving; Peer Review, which encourages mutual correction, enhancing cooperation in problem-solving; and Cooperative Graffiti, where groups record ideas, discuss different contributions, and present conclusions, stimulating creativity and confidence.

Another relevant structure is the Think Aloud Pairs Problem Solving (TAPPS) method, in which students work in dyads, alternating between the roles of problem-solver and listener. The problem-solver verbalizes each step of the reasoning process, while the listener monitors questions and supports the explanation without intervening directly. This method enhances metacognition, clarity of thought, and justification of ideas, contributing to the development of critical thinking dispositions (Mashuri et al., 2018; Silva et al., 2022).

These methods, by favoring cooperation, facilitate the development of critical thinking skills such as interpretation, analysis, evaluation, inference, and explanation, as well as dispositions such as truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, inquisitiveness, and cognitive maturity (Harahap & Harahap, 2022; Lopes & Silva, 2022; Suryani & Mashuri, 2023).

1.2. Cooperative Learning in Mathematics Education

The teaching of Mathematics requires complex cognitive processes; however, many students resort to memorization without deeply understanding the concepts (Muñiz & Miranda, 2017). Cooperative learning emerges as an effective approach, promoting interaction and a more active environment where exchanging ideas facilitates content comprehension (Lopes & Silva, 2022). Studies show that cooperative practices improve critical thinking, academic performance, and motivation, strengthening argumentation and problem-solving (Akinoso et al., 2021; Klang et al., 2021; Kovács et al., 2020; Noviati & Sinaga, 2021; Yulianto et al., 2023). Methods such as Student Teams—Achievement Divisions (STAD), Think-Pair-Share, Peer Review, and Cooperative Graffiti encourage communication and analysis, which are fundamental for mathematical learning (Lopes & Silva, 2022). The Think-Pair-Share has proven effective in teaching linear algebra, promoting more meaningful interaction and understanding of the content (Mashuri et al., 2018). Additionally, cooperative methods contribute to creating a more equitable and inclusive environment (Kovács et al., 2020).

1.3. Critical Thinking Dispositions in Mathematics

Critical thinking is a metacognitive process consisting of a set of abilities (cognitive dimension) and dispositions (affective dimension) that, through intentional and self-regulatory reflective judgment, increase the likelihood of producing a logical solution to a problem or a valid conclusion to an argument (Dwyer, 2017). Facione (2011) identifies six key competencies: interpretation, analysis, evaluation, inference, explanation, and self-regulation, which are fundamental for understanding, analyzing, and justifying information. In addition to cognitive competencies, critical thinking involves dispositions (Figure 2) such as open-mindedness, systematicity, inquisitiveness, self-confidence, truth-seeking, analyticity, and cognitive maturity, which influence the approach to problems and decision-making (Paul & Elder, 2006).

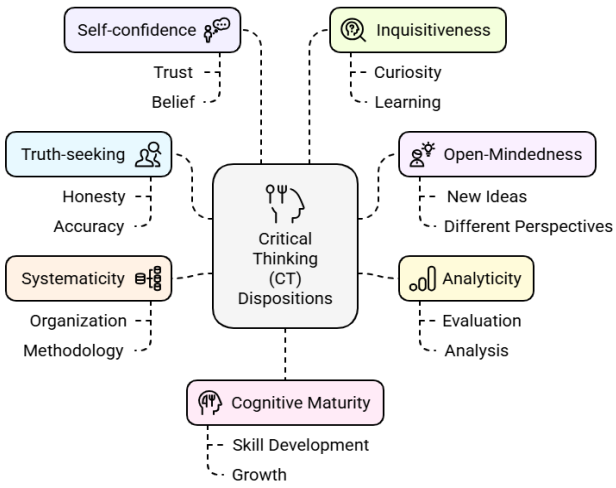

Figure 2 – Critical Thinking (CP) dispositions: subscales
Source: Infographic created in Napkin with data from the author

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In the teaching of Mathematics, critical thinking dispositions are fundamental for problem-solving, encouraging persistence and autonomous application of concepts. Studies show that students involved in practices that emphasize problem analysis and discussion exhibit higher levels of critical thinking than more traditional methods (Arisoy & Aybek, 2021; Morais et al., 2023).
Cooperative learning has proven particularly effective by promoting argumentation, the confrontation of perspectives, and collaborative problem-solving (Hartsfield et al., 2021; Klang et al., 2021; Siagian et al., 2023; Silva et al., 2018). Strategies that encourage mathematical communication and debate consolidate these dispositions, making teaching Mathematics more critical and reflective (Wahyudi et al., 2022).
Despite the positive results of cooperative learning, research on its impact on developing critical thinking dispositions in Mathematics A at the secondary education level remains scarce. Existing studies focus primarily on higher education contexts or non-specific subjects, leaving the systematic exploration of the influence of cooperative practices on the consolidation of dispositions in secondary school students largely unexplored (Aliu & Raheem, 2023; Arisoy & Aybek, 2021; Catarino et al., 2021; Klang et al., 2021; Lopes et al., 2021; Silva et al., 2018). Furthermore, the Portuguese educational context has been scarcely analyzed in this domain, creating a gap in understanding the role of cooperative learning in promoting critical thinking in Mathematics A (Morais et al., 2023).
In this sense, the present study aims to fill this gap by analyzing how cooperative learning can contribute to the development of critical thinking dispositions in secondary school students in Mathematics A, according to the *Profile of Students at the End of Compulsory Education* and *Essential Learnings* (Martins et al., 2017; DGE, 2018).

2. METHODS

This quasi-experimental study (Euzébio et al., 2021) analyzed the impact of cooperative learning on critical thinking dispositions in 11th-grade Mathematics A students in pre and post-test, comparing an experimental group subjected to cooperative methodologies with a control group that followed a more traditional teaching method. The intervention took place between January 15 and May 24, 2024, during 60 classes of 50 minutes each, over 13 weeks, covering the domains of Real Sequences and Rational Functions in the 11th-grade Mathematics A curriculum.
At the beginning of the experiment, the Cooperative Learning Scale (CLS), the Critical and Creative Thinking Test (CCTT), the Mathematics Knowledge Test (MKT), and the Critical Thinking Dispositions Scale (CTDS) were applied to both groups to assess initial critical thinking abilities and dispositions. As per the initial objective of this communication, only the analysis of the results obtained in the Critical Thinking Dispositions Scale (CTDS) will be carried out.

2.1 Sample

The sample included 119 students from a school located in the northern region of Portugal, divided into two equivalent groups: an experimental group (70 students), who participated in cooperative activities, and a control group (49 students), who attended more expository classes complemented by individual exercise solving.

2.2 Data collection instruments

Data collection focused on the results of the Critical Thinking Dispositions Scale (CTDS), validated for the Portuguese population by Lopes et al. (2021). The assessment instrument in question includes 35 items organized into seven subscales: truth-seeking (4 items), open-mindedness (4 items), analyticity (4 items), systematicity (7 items), self-confidence (5 items), inquisitiveness (7 items), and cognitive maturity (4 items). Participants answered on a Likert scale from 1 (Totally disagree) to 5 (Totally agree), as represented in Figure 2.
The score for each subscale varies between 10 and 50 points, and the total scores are between 70 and 350 points, with higher values reflecting a greater predisposition to critical thinking.
The internal consistency of the scale, namely its reliability using Cronbach's alpha, ranges from 0.62 to 0.93.
The interpretation of the results followed the criteria of Lopes et al. (2021), who classified the disposition levels into four categories, both for the subscales and the total score of the Critical Thinking Dispositions Scale (Table 1).

Table 1 - Levels of dispositions for Critical Thinking (CT) on each subscale and in the total of the CTDS

Levels	Subscales CTDS scores	Total CTDS scores
High disposition to CT	score 40 or higher	score 280 or higher
Positive disposition to CT	score between 30 and 39.9	score between 210 and 279.9
Ambivalent disposition to CT	score between 20 and 29.9	score between 140 and 209.9
Low disposition to CT	score less than 20	score less than 140

2.3 Statistical analysis

The data were subjected to descriptive analysis, followed by inferential analysis, to evaluate the effect of cooperative learning on the development of critical thinking dispositions in 11th-grade Mathematics A students. Initially, a descriptive analysis of the scores on the Critical Thinking Dispositions Scale (CTDS) was carried out, and the disposition levels were categorized.

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Tests for normality and homogeneity were conducted to assess the data distribution. Since most variables did not follow a normal distribution, non-parametric analyses were applied. The Wilcoxon test was used for paired samples, while the Mann-Whitney test was employed for independent samples to compare pre and post-test results within each group.
The analyses were carried out using the IBM SPSS Statistics 29.0 program, with a significant level of 5.0% ($p<.05$). The independent variable "gender" was included to assess possible influences on the development of critical thinking dispositions.

2.3.1. Classification of Critical Thinking Disposition Levels

The initial analysis focused on classifying the levels of critical thinking disposition based on the Critical Thinking Dispositions Scale (CTDS) scores, according to the criteria defined by Lopes et al. (2021). The levels of critical thinking disposition were classified as high, positive, ambivalent, or low. Table 2 shows the distribution of students in experimental and control groups at each level of disposition in the pre and post-test.
Although the inferential analysis of the pre-test results did not show statistically significant differences between the experimental and control groups ($p>.05$), descriptive data reveal that the proportion of students with high critical thinking dispositions was higher in the experimental group, particularly in the total CTDS score (45.7% vs. 26.5%). These differences were acknowledged and considered in the interpretation of the post-test results, in line with the nature of quasi-experimental designs.

Table 2 - Levels of disposition of the experimental and control groups in the pre and post-test of the Critical Thinking Dispositions Scale (CTDS)

CT Dispositions	Groups	Disposition levels	Pre-test		Post-test	
			N	%	N	%
Truth-seeking	Experimental	Ambivalent disposition	1	1.4	1	1.4
		Positive disposition	18	25.7	8	11.5
		High disposition	51	72.9	61	87.1
	Control	Ambivalent disposition	1	2.0	1	2.0
		Positive disposition	21	42.9	15	30.6
		High disposition	27	55.1	33	67.4
Open-mindedness	Experimental	Ambivalent disposition	3	4.3	1	1.4
		Positive disposition	33	47.1	13	18,6
		High disposition	34	48.6	56	80.0
	Control	Ambivalent disposition	1	2.0	2	4.1
		Positive disposition	30	61.2	20	40.8
		High disposition	18	36.8	27	55.1
Analyticity	Experimental	Ambivalent disposition	1	1.4	-	-
		Positive disposition	30	42.9	20	28.6
		High disposition	39	55.7	50	71.4
	Control	Ambivalent disposition	4	8.1	3	6.1
		Positive disposition	30	61.2	21	42.9
		High disposition	15	30.6	25	51.0
Systematicity	Experimental	Ambivalent disposition	1	1.4	-	-
		Positive disposition	22	31.5	12	17.1
		High disposition	47	67.1	58	82.9
	Control	Ambivalent disposition	-	-	2	4.1
		Positive disposition	28	57.1	17	34.7
		High disposition	21	42.9	30	61.2
Self-confidence	Experimental	Ambivalent disposition	6	8.6	1	1.4
		Positive disposition	42	60.0	32	45.7
		High disposition	22	31.4	37	52.9
	Control	Ambivalent disposition	3	6.1	7	14.3
		Positive disposition	34	69.4	22	44.9
		High disposition	12	24.5	20	40.8
Inquisitiveness	Experimental	Ambivalent disposition	2	2.9	1	1.4
		Positive disposition	26	37.1	18	25.7
		High disposition	42	60.0	51	72.9
	Control	Ambivalent disposition	-	-	2	4.1
		Positive disposition	31	63.3	20	40.8
		High disposition	18	36.7	27	55.1
Cognitive maturity	Experimental	Ambivalent disposition	1	1.4	-	-
		Positive disposition	23	32.9	17	24.3
		High disposition	46	65.7	53	75.7
	Control	Ambivalent disposition	1	2.0	2	4.1
		Positive disposition	27	55.1	23	46.9
		High disposition	21	42.9	24	49.0
CTDS Total score	Experimental	Ambivalent disposition	1	1.4	-	-
		Positive disposition	37	52.9	21	30.0
		High disposition	32	45.7	49	70.0
	Control	Ambivalent disposition	-	-	1	2.0
		Positive disposition	36	73.5	28	57.2
		High disposition	13	26.5	20	40.8

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The analysis of Table 2, in the pre-test, shows a predominantly positive disposition in all the dimensions assessed, particularly about truth-seeking, in which 72.9% of the students in the experimental group and 55.1% in the control group showed a high disposition.

After the intervention, the experimental group showed a significant improvement in all the subscales, with an increase in high disposition from 72.9% to 87.1% in truth-seeking, from 48.6% to 80.0% in open-mindedness and from 67.1% to 82.9% in systematicity. In the total score of the Critical Thinking Dispositions Scale (CTDS), a high disposition was observed, which increased from 45.7% in the pre-test to 70.0% in the post-test.

The control group had a less marked increase, with the high disposition rising from 26.5% to 40.8%. This result indicates a small effect of the more traditional teaching methodology (z=.31 and p=.754), suggesting that the improvement is not statistically significant.

Figure 3 provides a graphical representation of the overall results from the Critical Thinking Dispositions Scale (CTDS), corresponding to the total scores reported in the last row of Table 3. It compares the distribution of pre and post-test results for both the experimental and control groups.

In the experimental group, a statistically significant improvement was observed in the total CTDS score from pre-test (M=279.98; SD=31.50) to post-test (M=297.64; SD=29.41), as indicated by the Wilcoxon test (*z*=3.52; p<.001; r=.42), suggesting a moderate effect size. This increase was accompanied by a visible reduction in score variance, indicating greater homogeneity in student performance after the intervention. The narrowing of differences suggests that students with initially lower levels of critical thinking dispositions improved considerably, approaching the performance levels of their higher-scoring peers.

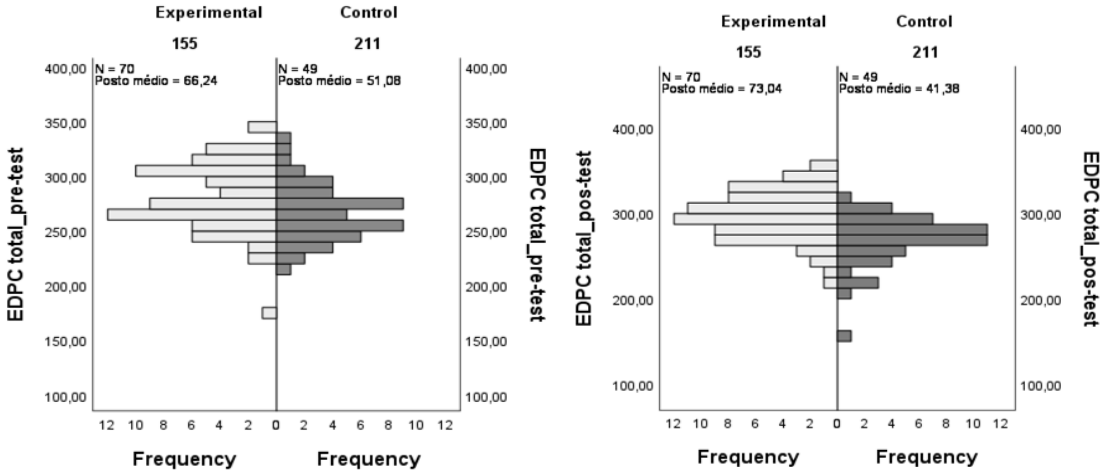

Figure 3 – Distribution of pre and post-test scores on the Critical Thinking Dispositions Scale (CTDS) for experimental and control groups

In contrast, the control group showed no statistically significant change between the pre-test (M=267.18; SD=26.10) and the post-test (M=267.82; SD=28.75), with the Wilcoxon test yielding non-significant results (*z*=.31; p=.754). These findings suggest that the traditional teaching methodology did not lead to measurable improvements in students' critical thinking dispositions.

The increase in mean scores across several subscales, together with the reduction in performance disparities observed in the experimental group, reinforces the potential of cooperative learning as an effective pedagogical approach for fostering critical thinking dispositions among secondary school students.

2.3.2. Comparison of Levels of Critical Thinking Dispositions between the Experimental and Control Groups in Pre and Post-test

Means and standard deviations from pre-test and post-test data were used for group comparisons. To verify the initial equivalence between groups, Mann–Whitney U tests were conducted on each subscale of the Critical Thinking Dispositions Scale (CTDS).

As shown in Table 3, the results revealed no statistically significant differences between the experimental and control groups at pre-test (p>.05), suggesting comparable baseline levels across all dimensions. Wilcoxon non-parametric tests, based on data ranks, were employed to assess changes between pre and post-test assessments within each group. These tests indicated significant improvements in the experimental group's CTDS subscale scores and total score following the intervention.

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Table 3 - Pre and post-test results of the Critical Thinking Dispositions Scale (CTDS) for experimental and control groups

CT Dispositions	Groups	Tests	N	Average	SD	*z*	p	r
Truth-seeking	Experimental	Pre-test	70	42.07	5.60	2.91	.004	.35
		Post-test		44.25	5.22			
	Control	Pre-test	49	39.85	5.87	.21	.838	-
		Post-test		39.64	5.18			
Open-mindedness	Experimental	Pre-test	70	39.39	5.97	3.64	<.001	.44
		Post-test		42.86	5.29			
	Control	Pre-test	49	38.42	5.17	.28	.781	-
		Post-test		38.57	5.42			
Analyticity	Experimental	Pre-test	70	39.61	5.31	2.76	.006	.33
		Post-test		42.11	5.21			
	Control	Pre-test	49	36.99	5.30	.55	.583	-
		Post-test		37.29	5.59			
Systematicity	Experimental	Pre-test	70	41.37	4.77	2.51	.012	.30
		Post-test		43.45	4.24			
	Control	Pre-test	49	39.42	4.36	.21	.831	-
		Post-test		39.24	4.84			
Self-confidence	Experimental	Pre-test	70	36.51	6.00	3.23	.001	.39
		Post-test		39.97	5.66			
	Control	Pre-test	49	35.63	5.04	.61	.542	-
		Post-test		36.86	10.16			
Inquisitiveness	Experimental	Pre-test	70	40.49	5.54	2.12	.034	.25
		Post-test		42.37	6.11			
	Control	Pre-test	49	38.44	4.70	.26	.797	-
		Post-test		38.51	4.62			
Cognitive maturity	Experimental	Pre-test	70	40.54	5.09	2.83	.005	.34
		Post-test		42.64	4.94			
	Control	Pre-test	49	38.42	4.47	.48	.628	
		Post-test		37.70	4.64			
CTDS Total score	Experimental	Pre-test	70	279.98	31.50	3.52	<.001	.42
		Post-test		297.64	29.41			
	Control	Pre-test	49	267.18	26.10	.31	.754	-
		Post-test		267.82	28.75			

Note: SD=Standard deviation; z=Wilkoson test; p=Statistical significance; r=Magnitude of effect

After the intervention, the results of the post-test in the experimental group indicate a statistically significant improvement in the total score of the CTDS score, with the average increasing from 279.98 (SD=31.50) to 297.64 (SD=29.41), as indicated by the Wilcoxon test (*z*=3.52; p<.001; r=.42). Additionally, significant improvements were found in several subscales: truth-seeking (*z*=2.91; p=.004; r=.35), open-mindedness (*z*=3.64; p<.001; r=.44), analyticity (*z*=2.76; p=.006; r=.33), and inquisitiveness (*z*=2.83; p=.005; r=.34). These results reflect moderate effect sizes in most dimensions.

On the other hand, the control group showed no statistically significant changes between pre-and post-test scores. The total CTDS score remained virtually unchanged, with an average of 267.18 (SD=26.10) in the pre-test and 267.82 (SD=28.75) in the post-test (*z*=.31; p=.754), indicating that the traditional methodology did not lead to meaningful improvements in students' critical thinking dispositions.

2.3.3. Gender Differences in Critical Thinking Dispositions in Pre and Pos-Test

The analysis of the influence of gender on critical thinking dispositions, based on the means and standard deviation in the two assessment moments (pre and post-test), showed statistically significant differences in the experimental group, with the female students showing a more marked evolution compared to the male students (Table 4).

The results of the post-test indicate that, in the experimental group, female students obtained significant improvements in subscales such as open-mindedness (from 38.57 to 43.21; *z*=3.316; p<.001; r=.63), inquisitiveness (from 38.98 to 42.20; *z*=2.347; p=.019; r=.44), and cognitive maturity (from 40.00 to 43.48; *z*=3.051; p=.002; r=.58). Additionally, the total score on the Critical Thinking Dispositions Scale (CTDS) increased from 274.37 to 301.06 (*z*=3.644; p<.001; r=.69), reflecting a statistically significant evolution.

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Table 4 – Pre and post-test results of the Critical Thinking Dispositions Scale (CTDS) for experimental and control groups by gender

Subscales	Groups	Gender	Pre-Test		Post-Teste				
			Average	Standard Deviation	Average	SD	*z*	p	r
Truth-seeking	Experimental	M (42)	42.20	4.88	44.17	5.02	2.001	.045	.31
		F (28)	41.88	6.62	44.38	5.59	2.093	.036	.40
	Control	M (22)	39.66	5.25	40.00	5.93	.470	.638	-
		F (27)	40.00	6.43	39.35	4.58	.585	.559	-
Open-mindedness	Experimental	M (42)	39.94	5.45	42.62	4.88	2.124	.034	.33
		F (28)	38.57	6.68	43.21	5.93	3.316	<.001	.63
	Control	M (22)	37.50	5.54	39.12	6.46	1.142	.253	-
		F (27)	38.80	4.92	37.96	4.44	.849	.396	-
Analyticity	Experimental	M (42)	39.76	4.74	41.07	5.39	1.067	.286	-
		F (28)	39.38	6.15	43.66	4.59	2.961	.003	.56
	Control	M (22)	36.02	5.33	36.25	6.93	.643	.520	-
		F (27)	37.78	5.25	38.15	4.14	.246	.806	-
Systematicity	Experimental	M (42)	41.56	4.63	43.12	4.60	1.511	.131	-
		F (28)	41.08	5.05	43.94	3.66	2.349	.019	.44
	Control	M (22)	38.38	4.47	39.16	5.53	.940	.347	-
		F (27)	40.27	4.15	39.31	4.31	.607	.544	-
Self-confidence	Experimental	M (42)	37.86	6.13	39.81	5.67	1.411	.158	-
		F (28)	34.50	5.30	40.21	5.74	3.234	.001	.61
	Control	M (22)	37.27	5.22	37.55	14.07	.593	.553	-
		F (27)	34.30	4.56	36.30	5.45	1.817	.069	.35
Inquisitiveness	Experimental	M (42)	41.50	5.01	42.28	5.33	.798	.425	.12
		F (28)	38.98	6.03	42.20	7.23	2.347	.019	.44
	Control	M (22)	38.89	4.97	38.57	5.84	.000	1.000	-
		F (27)	38.08	4.53	38.46	3.43	.324	.746	-
Cognitive maturity	Experimental	M (42)	40.89	5.02	42.08	4.91	1.035	.301	-
		F (28)	40.00	5.23	43.48	4.97	3.051	.002	.58
	Control	M (22)	37.95	3.98	37.73	5.17	.122	.903	-
		F (27)	38.80	4.87	37.69	4.27	.749	.454	-
CTDS Total score	Experimental	M (42)	283.72	29.06	295.36	29.59	1.707	.088	.26
		F (28)	274.37	34.62	301.06	29.32	3.644	<.001	.69
	Control	M (22)	266.15	25.50	268.57	36.84	.455	.649	-
		F (27)	268.03	27.04	267.22	20.71	.060	.952	-

Note: M=Male; F=Female; SD=Standard deviation; *z*= Wilkoson test; p=Statistical significance; r= Effect size

Male students in the experimental group also showed statistically significant, though more moderate, improvements, particularly in truth-seeking (from 42.20 to 44.17; *z*=2.001; p=.045; r=.31) and open-mindedness (from 39.76 to 41.07; *z*=2.124; p=.034; r=.33). In the control group, there were no statistically significant differences between genders in any of the subscales or the total score of the Critical Thinking Dispositions Scale (p>.05), indicating that the traditional methodology did not influence the development of critical thinking dispositions in either gender.

3. RESULTS

This study compared the effectiveness of cooperative learning with traditional teaching methods in promoting critical thinking skills in 11th-grade Math A students. Initially, the analysis of the pre-tests indicated similar conditions between the experimental and control groups. However, after the intervention, the experimental group showed significant improvements in the truth-seeking, open-mindedness, and systematicity subscales, with the total score on the Critical Thinking Dispositions Scale (CTDS) increasing from 279.98 to 297.64, showing a statistically significant improvement in critical thinking dispositions. The control group remained stable throughout the experiment.

The influence of gender proved statistically significant in the experimental group, with female students showing more marked improvements, particularly in open-mindedness, inquisitiveness, and cognitive maturity, and male students improving especially in truth-seeking. These results are detailed in Table 4.

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The longitudinal study of dispositions towards critical thinking showed a trend towards homogenization in the experimental group, with a substantial increase in the number of students achieving high levels of disposition, from 45.7% to 70.0%. The control group also recorded an increase, from 26.5% to 40.8%. Although both groups showed a similar relative growth (approximately 53%), the experimental group maintained a higher overall proportion of students with high levels of critical thinking disposition.

4. DISCUSSION

The results of this study corroborate the relevance of cooperative learning for the development of critical thinking skills in 11th-grade Math A students, validating the effectiveness of this methodology (Erdogan, 2019; Klang et al., 2021; Lopes et al., 2021).
The intervention showed substantial gains in all subscales of the Critical Thinking Dispositions Scale (CTDS), especially in truth-seeking, open-mindedness, and systematicity.
Statistical analysis using the Mann–Whitney U test showed no significant differences ($p>.05$) between the experimental and control groups in the pre-test, confirming equivalent initial conditions for the study (Zakaria et al., 2010). The significant evolution in critical thinking dispositions observed in the experimental group after the intervention points to the effectiveness of cooperative learning in promoting these dispositions, in line with studies that highlight the benefits of cooperative methodologies such as STAD, Think Aloud Pairs, and Cooperative Graffiti (Harahap & Harahap, 2022; Lopes & Silva, 2022; Suryani & Mashuri, 2023).
The application of the Think Aloud Pairs Problem Solving (TAPPS) method, in which one student verbalizes their reasoning while the other listens, monitors, and questions, when necessary, allowed students to make their thinking explicit and reflect on it, strengthening metacognition and the ability to justify solutions (Mashuri et al., 2018; Silva et al., 2022). Meanwhile, the STAD method reinforced individual and collective responsibility, creating an environment conducive to sharing and critically evaluating solutions (Silva et al., 2022).
Regarding gender, the results indicated a statistically more significant improvement in female students in the experimental group, especially in open-mindedness and inquisitiveness (Klang et al., 2021; Kovács et al., 2022;). The exchange of arguments and the confrontation of ideas in a cooperative context seem to favor female students more, facilitating the development of critical thinking dispositions essential for mobilizing reasoning, argumentation, and problem-solving skills (Mashuri et al., 2018). In male students, the gains were less expressive but still statistically significant, reinforcing the idea that cooperative learning promotes critical thinking dispositions across genders (Arisoy & Aybek, 2021).
These results confirm that cooperative learning is an effective pedagogical strategy for developing critical thinking skills in mathematics, reinforcing the contribution of this methodology to academic success and the construction of logical and structured reasoning (Erdogan, 2019; Klang et al., 2021; Lopes & Silva, 2022).

CONCLUSION

The results prove the positive impact of cooperative learning on the development of critical thinking skills in 11th-grade Math A students, with more significant gains in truth-seeking, open-mindedness, systematicity, fundamental problem-solving, and logical reasoning skills.
The experimental group showed substantial improvements compared to the control group, which, using a more conventional teaching methodology, showed no significant changes. These results reinforce the effectiveness of cooperative learning in promoting critical thinking skills and highlight the limitations of traditional teaching focused on theoretical exposition.
The intervention also reduced inequalities in performance, allowing students with lower results to keep up with their peers' progress.
These results validate cooperative learning as a promoter of critical thinking skills as an effective strategy for teaching Mathematics A, as it stimulates interaction, collaboration, and critical analysis, in line with the recommendations of the *Profile of Students Leaving Compulsory Schooling* and *Essential Learning*.
Given that female students obtained better results than male students in the study, further research is needed to ascertain the reasons for these results and to create more favorable and equitable conditions.

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AUTHORS' CONTRIBUTION

Conceptualization, M.M, H.S. and J.L.; data curation, M.M, H.S. and J.L..; formal analysis, M.M, H.S. and J.L.; investigation, M.M, H.S. and J.L.; methodology, M.M, H.S. and J.L.; resources, M.M, H.S. and J.L.; software, M.M, H.S. and J.L.; supervision, M.M, H.S. and J.L.; validation, M.M, H.S. and J.L.; visualization, M.M, H.S. and J.L.; writing-original draft, M.M, H.S. and J.L.; writing-review and editing, M.M., H.S. and J.L.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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