

Critical Thinking and Environmental Problem Solving: Evaluation of an Educational Intervention in a Rural School

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ABSTRACT:

The development of critical thinking in rural education is essential for bridging cognitive gaps and fostering active citizenship in the face of territorial biophysical crises. The objective of this article was to evaluate the impact of a teaching intervention based on solving environmental problems to enhance critical thinking among rural lower secondary students in the department of Caquetá, Colombia. Methodologically, a quantitative approach was implemented using a pre-experimental pretest-posttest design with a census sample of 41 students in sixth and seventh grades. The variable was operationalized according to Tamayo's taxonomy, measuring four progressive levels (descriptive, simple explanatory, explanatory with justification, and critical-propositional) using a validated psychometric questionnaire ($\alpha = 0.957$) structured around five environmental thematic areas. The results revealed a statistically significant cognitive shift following the intervention ($p < 0.001$ according to the Wilcoxon test) in all areas assessed. Students progressed from baseline levels that were predominantly "explanatory with justification" and "simple explanatory" toward the highest level, "critical-propositional," with the theme of climate change standing out as the area of greatest analytical advancement and sustainable production as the area of greatest metric precision. It is concluded that the systematic and flexible inclusion of local issues in curriculum design—moving beyond isolated workshops—serves as an efficient driver of pedagogical transformation. This strategy reduces conceptual abstraction and optimizes students' argumentative and propositional skills, overcoming the structural and technological limitations of the rural environment..

Keywords: critical thinking, levels, students, education, pedagogical intervention

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Introduction

Developing critical thinking in today's middle school students requires moving beyond the traditional view of education based on the mere accumulation of conceptual content. In this regard, the scientific literature considers this comprehensive skill to be an advanced cognitive process that enables students to recognize and analyze information objectively, to evaluate the arguments presented and, consequently, make informed decisions (Elera et al., 2023). From a constructivist and metacognitive perspective, leading authors such as Facione, Paul and Elder, and Ennis agree that this construct truly integrates essential skills of analysis, inference, and self-regulation aimed at subjecting one's own thinking to evaluation and criticism based on intellectual standards to improve it when faced with multidimensional situations (Betancourt & López, 2023; Roza & Calvache, 2024). Thus, the acquisition and subsequent consolidation of these reflective skills are necessary within the students' sociocultural context, primarily because they are at an age when they are developing their cognitive autonomy and transforming their reality.

Integrating these theoretical models provides secondary educators with an ideal tool for designing learning experiences aimed at encouraging students to develop their thinking to a higher level. This conceptual framework not only enriches daily classroom practice but also highlights critical thinking as an indispensable, malleable, and assessable skill that fosters the maturation of mental capacity to shape reflective citizens (Barrio et al., 2025; Córdoba, 2024). Furthermore, this process can be linked to the period when students enter Piaget's stage of formal operations and acquire the hypothetical-deductive reasoning necessary to support their cognitive autonomy (Tantajulca, 2024). Therefore, harnessing this neuropsychological potential through active teaching methodologies and context-based interventions becomes the ideal path to bridge learning gaps and transform traditional classrooms into settings for applied critical thinking.

Despite adolescents' cognitive potential, experience reveals a gap between theoretical demands and the critical thinking skills that students develop. Systematic reviews in Latin America confirm this perception that students continue to suffer from shortcomings in analysis and decision-making associated with rigid curricula, the persistence of rote-learning practices, and a historical bias that relegated this education to the university setting (Castro & Franco, 2025; Fernández, 2024; Garagundo, 2022). This problem is exacerbated when teachers fail to recognize the cross-curricular value of critical thinking and when there are no professional development opportunities (Dewi et al., 2025; Poveda & Calvache, 2024). Therefore, overcoming this pedagogical dissonance requires a methodological renewal that transcends the technical neutrality of the classroom, reviving sociopolitical and constructivist approaches in which discussion and language enable students to actively transform their own environment (Garagundo, 2022; Nava, 2025). This urgency for pedagogical transformation is heightened when the debate is shifted to rural educational institutions, whose contexts of vulnerability demand immediate pedagogical responses.

The development of critical thinking must transcend the individual cognitive level to be directly linked to the exercise of active citizenship and sustainable development. From the perspectives of cultural psychology and critical pedagogy, the classroom is conceived as a setting where knowledge is a social construct aimed at understanding the sociocultural context, identifying local needs, and solving everyday problems (Escobar, 2024; Uribe & Gutiérrez, 2023). However, the implementation of strategies aimed at developing this competency requires that teachers also possess a cross-cutting critical mindset that serves as an example for their students and enables the actual execution of these strategies in classroom planning (Aspur, 2023; López et al., 2022; Poveda & Calvache, 2024). Consequently, the commitment of the teaching staff is essential to transforming traditional sessions into spaces that foster the evolution of ideas and purposeful argumentation, particularly

in regions where geographical and environmental realities pose additional challenges to teaching.

Overcoming these gaps also requires an institutional culture that prioritizes personal development by normalizing highly effective pedagogical strategies. In this regard, active learning approaches have been shown to have a positive impact on students' complex cognitive skills and logical reasoning (Bermeo et al., 2025). These approaches are typically based on experiential methodologies—Problem-Based Learning (PBL) and Project-Based Learning (PBL)—that place students in real-world, collaborative scenarios to stimulate inference, creativity, and argumentative mapping (Quispe, 2025). The integration of models focused on information seeking, real-world case studies, and applied technologies helps foster critical thinking in line with individual learning paces and cultural diversity (Lassonde, 2025; Ossa & Mena, 2022). Thus, the implementation of these innovative teaching methods provides the practical support needed to inform relevant pedagogical decisions in traditionally underserved school contexts.

Evidence confirms that the systematic application of teaching methods geared toward critical thinking has a significant impact on the cognitive performance of secondary school students. Quasi-experimental studies demonstrate that the use of argumentative debates, critical reading, and digital tools—supported by rigorous pedagogical planning—strengthens students' ability to tackle complex real-world problems (Elera et al., 2023; Gallardo, 2025; Ibarvo et al., 2024). Furthermore, the integration of creative strategies strengthens student engagement, fostering alignment with a flexible curriculum, which creates an ideal setting for the sustained development of high-level competencies (Espinola & Santos, 2022; Grefa et al., 2025). Against this backdrop, it is imperative to examine the effectiveness of these approaches in settings with critical socio-environmental challenges; therefore, the objective of this article is to evaluate the impact of a teaching intervention based on solving environmental problems on the development of critical thinking among students in rural lower secondary

education in the department of Caquetá, Colombia.

Methodology

This study employed a quantitative approach with a single-group pre-test/post-test pre-experimental design and an explanatory-evaluative scope. Using non-probabilistic convenience sampling, a census sample of 41 students formally enrolled in sixth and seventh grades at the La Esmeralda Rural Educational Institution, located in the department of Caquetá, Colombia, was selected. The process received institutional approval, and the legal guardians signed the informed consent forms.

Variables and Instruments

The central variable, "Critical Thinking in Environmental Problem Solving," was operationalized using Tamayo's (2019) analytical taxonomy, which establishes an ordinal scale with four progressive levels:

1. Descriptive (value 1)
2. Simple explanatory (value 2)
3. Explanatory with justification (value 3)
4. Critical-proactive (value 4)

To measure this variable, a structured psychometric questionnaire was developed, consisting of 20 multiple-choice questions with ordinal scaling, contextualized within ecological problem situations in the Amazon region. The instrument underwent content validation through expert judgment and demonstrated excellent internal consistency, yielding an overall Cronbach's alpha coefficient of 0.957. The 20 items were distributed evenly across two analysis matrices (one oriented toward Facione's dimensions and the other structured around five environmental thematic axes):

- Water management (P1, P5, P16)
- Biodiversity (P2, P4, P8, P14)
- Climate change and risk management (P3, P10, P12, P18)
- Sustainable production (P6, P9, P11, P17, P20)

- Waste management and pollution (P7, P13, P15, P19)

Procedure and Pedagogical Intervention

The research was conducted in three consecutive phases:

- Phase 1 (Pre-test): Initial administration of the questionnaire to establish a baseline assessment of critical thinking among schoolchildren regarding the five environmental themes.
- Phase 2 (Intervention): Implementation of a teaching sequence based on solving environmental problems, explicitly integrated into the lesson plans for the grades evaluated during the regular academic term.
- Phase 3 (Posttest): Re-administration of the questionnaire under identical psychometric conditions to assess changes in cognitive levels following the intervention.

Data Analysis

Statistical analysis was performed using R Studio software. Descriptive statistics (means and standard deviations) were used to characterize the sample and the variables; to evaluate the metric quality of the instrument at both time points, analyses based on Classical Test Theory (CTT) were applied, specifically calculating the Difficulty Index (p)—where higher values indicate a greater proportion of correct answers or highly complex responses—and the Discrimination Index (d), used to verify the effectiveness of the questions in distinguishing between different levels of students' critical thinking performance. Likewise, to determine whether the increase in means between the initial assessment (pretest) and the final assessment (posttest) was statistically significant and not due

to chance, the Wilcoxon signed-rank test for paired samples (or Student's t-test, depending on the normality criteria) was applied, setting a standard significance level of $\alpha = 0.05$.

Results

The sociodemographic profile of the census sample confirms the homogeneity of the study group within the age ranges corresponding to lower secondary education. The descriptive analysis shows that all participants (N=41) fall within the 10- to 15-year-old age range, with the majority (54%, n=22) in the 12- to 13-year-old age group, followed by 27% (n=11) in the 14- to 15-year-old age group. Regarding gender distribution, males predominate, accounting for 56% (n=23) of the sample, compared to 39% (n=16) of females and 5% (n=2) who chose not to disclose this information. This demographic profile places the student body of the rural school in Caquetá in early adolescence, a developmental stage ideally suited for stimulating complex cognitive operations through environmental pedagogical mediation.

The first sectoral analysis (Table 1) focused on evaluating the participants' ability to resolve dilemmas associated with water resources, one of the most sensitive issues in the Amazonian ecosystem. In this regard, the pretest data place the group at a level of explanatory thinking with justification, characterized by a partial recognition of the causes of water degradation, but with limitations in structuring applied solutions. However, following the implementation of the educational intervention, the final assessment (posttest) demonstrates a statistically significant cognitive shift toward the critical-proactive level, reaching an average of 3.40.

Table 1. Metric and Psychometric Results for the Water Management Axis.

Assessment / Phase	Thematic Axis	Mean	Standard Deviation (SD)	p-value (Wilcoxon)	Thinking Levels	Difficulty Index	Discrimination Index
Pretest	Water management	2.84	0.96	<0.001	Explanatory with	0.71	0.82

	nt (P1, P5, P16)				justificatio n		
Posttest		3.40	0.79		Critical- propositiv e	0.85	0.82
Pretest	Biodiversty (P2, P4, P8, P14)	2.73	0.90	<0.001	Explanator y with justificatio n	0.68	0.91
Posttest		3.46	0.69		Critical- propositiv e	0.86	0.85
Pretest	Climate change and risk (P3, P10, P12, P18)	2.54	0.92	<0.001	Simple explanator y	0.63	0.92
Posttest		3.50	0.63		Critical- propositiv e	0.88	0.89
Pretest	Sustainable production (P6, P9, P11, P17, P20)	2.62	0.96	<0.001	Explanator y with justificatio n	0.65	0.94
Posttest		3.43	0.70		Critical- propositiv e	0.86	0.95
Pretest	Waste manageme nt and pollution (P7, P13, P15, P19)	2.64	0.88	<0.001	Explanator y with justificatio n	0.66	0.87
Posttest		3.48	0.76		Critical- propositiv e	0.87	0.93

Source: Author's own work

The second assessment block (Table 1) examined the development of critical thinking as applied to the theme of biodiversity, a scenario in which students were required to resolve dilemmas focused on species conservation and the dynamics of local ecosystems. In the baseline assessment (pretest), students scored at the “explanatory with justification” level; this indicates that, although they were able to identify basic ecological relationships, their arguments

lacked a proactive and structured approach to conservation. Following the instructional intervention, the posttest showed a statistically significant improvement toward the “critical-proactive” level.

The third sectoral analysis (Table 1) addressed the theme of Climate Change and Risk Management, a scenario that represented the most acute initial cognitive challenge for the students at the

institution. On the pretest, the group recorded the lowest baseline mean, placing them at a level of simple explanatory thinking, which reflects a linear, fragmented, and atomized understanding of climate phenomena and their associated risks. However, following the implementation of the instructional proposal, the posttest revealed the most significant cognitive progress. This transformation is validated by the difficulty index. Furthermore, the discriminatory power of this theme remained within ranges of psychometric excellence.

The fourth sectoral analysis (Table 1) evaluated the Sustainable Production axis, a highly complex component that requires linking critical reasoning with socioeconomic viability and territorial environmental impacts. In the diagnostic phase (pretest), the students were at the “explanatory with justification” level. Following the implementation of the instructional sequences, the posttest revealed statistically significant progress toward the critical-proactive level. This domain stands out as having the highest metric precision of the entire instrument, confirming that pedagogical mediation transformed originally abstract content into an assimilated and proactive learning scenario for the rural context.

The fifth and final sectoral analysis (Table 1) examined the development of cognitive skills applied to the axis of Waste Management and Pollution, a topic with high empirical visibility in the local community context. In the baseline measurement (pretest), the assessment placed the group at the level of explanatory thinking with justification. With a comparatively lower dispersion than that observed in the other domains, this indicates a prior collective familiarity with the issue of waste, although limited to linear reasoning about causes without progressing to the formulation of viable mitigation alternatives.

Discussion

The purpose of this study was to evaluate the impact of a teaching intervention based on solving real-world environmental problems, with the aim of developing critical thinking skills among lower secondary school students at a rural

school in Caquetá. When comparing the pretest and posttest phases using the nonparametric Wilcoxon test, statistically significant differences ($p < 0.001$) were found across all five thematic areas. These changes in student performance corroborate the thesis of Ibarvo et al. (2024), who argue that the inclusion of directly structured active methodologies in the secondary education curriculum design leads to superior cognitive development compared to linear teaching approaches based on the reproduction and memorization of theoretical content.

An analysis of the Climate Change and Risk Management thematic area reveals the lowest initial mean score of the entire study. This finding indicates that global concepts related to climate variation are initially perceived in rural schools as abstract notions disconnected from the local geography. The pedagogical intervention, for its part, was able to reduce the intrinsic complexity, transforming an abstract subject of study into a learning scenario that the group could internalize. Meanwhile, the themes of Water Management and Biodiversity demonstrate the effectiveness of grounding pedagogical mediation in the biophysical reality of the Colombian Amazon. The transition from the explanatory-justification level to the critical-propositional level is associated with a greater ability to propose well-founded mitigation alternatives, moving beyond the purely descriptive phase of ecological damage.

This result aligns with the empirical evidence from Espinola and Santos (2022), who demonstrate that linking problem-solving to community interests and local life plans enhances conceptual retention and environmental awareness in early adolescence. The Sustainable Production domain provided the most robust psychometric data for the instrument, recording the highest discrimination indices in the entire study. In psychometric terms, problems that pit the region’s agricultural and economic development against the ecological limits of the biome are considered optimal tools for assessing multidimensional thinking.

This finding is consistent with the model proposed by Elera et al. (2023), which argues that logical-conceptual reasoning requires a structured pedagogical environment that critically evaluates available information. The connectivity limitations of the rural institution under study necessitate greater rigor in the logical design of the learning guides in order to effectively compensate for technological shortcomings, thereby stimulating the same analytical processes that occur in hyperconnected environments. The Waste Management and Pollution track continued this trend of progress; however, the value of the instructional design lies in providing a logical structure to this everyday knowledge, guiding students from passively identifying waste to a critical and proactive level.

The convergence of these results across the five analyzed areas strengthens higher-order intellectual skills in secondary education thanks to curricular flexibility and the implementation of ongoing programs, thereby eliminating the need for isolated workshops or temporary extracurricular activities. All of this helps mitigate the infrastructure limitations in rural areas that typically hinder students' cognitive development.

Conclusions

The implementation of a structured instructional intervention based on solving real-world environmental problems serves as a method for developing critical thinking skills in rural lower secondary education. A comparative inferential analysis of the pretest and posttest confirms that integrating local environmental issues into the curriculum brings about a positive change in students' abilities to reason and propose solutions. This change encourages a shift from passive, rote-learning approaches to complex cognitive structures, enabling students to formulate well-founded mitigation strategies in response to the ecological crises affecting their region.

The impact of the pedagogical strategy varies depending on the nature of each thematic area, being closely linked to the empirical relevance of the problem. In components with a high initial level of abstraction, didactic mediation works by reducing the conceptual complexity of the subject matter, which facilitates the assimilation of broad concepts and their subsequent application to the local context.

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