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Causal Reasoning in Argumentative Contexts in the Classroom

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Abstract

The current education system in Colombia demands the development of scientific reasoning as a foundation for teaching and learning processes in the classroom. However, research has shown that students face difficulties with inferential processing and critical comprehension, which limits their ability to analyze and synthesize information and to solve complex problems. This study aims to describe the development of causal reasoning in secondary school students within a learning context based on argumentation around socio-scientific issues, highlighting the need to explore how this type of reasoning emerges and how it can be strengthened. A qualitative approach was adopted, privileging a dialogic-discursive analysis of argumentative productions from 150 cases selected through purposive sampling, identifying patterns and levels of causal relationships. The results reveal that causal relationships in students' argumentative productions are predominantly multicausal, and that the structure of causal argumentation becomes progressively more complex as the number of statements included in viewpoints increases, as well as the types of causal relationships established between justifications and viewpoints, and among different argumentative lines. These findings suggest the need to engage students in activities that explicitly promote inferential processes and more complex ways of structuring reasoning. Consequently, the study proposes implementing strategies based on the mediation of argumentative reasoning as a tool for the development of causal reasoning, thereby fostering actions oriented towards strengthening it.

Keywords

reasoning; argumentation; education; adolescence

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Raciocínio causal em contextos argumentativos de sala de aula

Resumo

O sistema educacional atual na Colômbia exige o desenvolvimento do raciocínio científico como base dos processos de ensino-aprendizagem em sala de aula. No entanto, pesquisas têm mostrado que os estudantes enfrentam dificuldades no processamento inferencial e na compreensão crítica, o que limita sua capacidade de analisar, sintetizar informações e resolver problemas complexos. Este estudo tem como objetivo descrever o desenvolvimento do raciocínio causal em estudantes do ensino médio em um contexto de aprendizagem baseado na argumentação sobre temas socio-científicos, destacando a necessidade de explorar como esse tipo de raciocínio se manifesta e como pode ser fortalecido. Adotou-se uma abordagem qualitativa, privilegiando uma análise dialógico-discursiva das produções argumentativas de 150 casos selecionados por amostragem intencional, identificando linhas e níveis de relações causais. Os resultados revelam que as relações causais presentes nas produções argumentativas dos estudantes são predominantemente multicausais, e que a estrutura da argumentação causal se torna progressivamente mais complexa à medida que aumenta o número de enunciados incluídos nos pontos de vista, a tipologia das relações causais estabelecidas entre justificativas e pontos de vista, bem como entre diferentes linhas argumentativas. Esses achados sugerem a necessidade de envolver os estudantes em atividades que promovam explicitamente processos inferenciais e formas mais complexas de estruturação do raciocínio. Em consequência, o estudo propõe a implementação de estratégias baseadas na mediação do raciocínio argumentativo como ferramenta para o desenvolvimento do raciocínio causal, impulsionando assim ações orientadas ao seu fortalecimento.

Palavras-chave

raciocínio; argumentação; educação; adolescência

Razonamiento causal en contextos argumentativos del aula

Resumen

El sistema educativo actual en Colombia exige el desarrollo del razonamiento científico como base de los procesos de enseñanza-aprendizaje en el aula. Sin embargo, investigaciones han mostrado que los estudiantes enfrentan dificultades en el procesamiento inferencial y la comprensión crítica, lo que limita su capacidad para analizar, sintetizar información y resolver problemas complejos. Este estudio tiene como objetivo describir el desarrollo del razonamiento causal en estudiantes de secundaria en un contexto de aprendizaje basado en la argumentación sobre temas socio-científicos, destacando la necesidad de explorar cómo se manifiesta este tipo de razonamiento y cómo puede fortalecerse. Se adoptó un enfoque cualitativo, privilegiando un análisis dialógico-discursivo de las producciones argumentativas de 150 casos seleccionados mediante muestreo intencional, identificando líneas y niveles de relaciones causales. Los resultados revelan que las relaciones causales presentes en las producciones argumentativas de los estudiantes son predominantemente multicausales, y que la estructura de la argumentación causal se vuelve progresivamente más compleja según aumenta el número de enunciados incluidos en los puntos de vista, la tipología de las relaciones causales establecidas entre las justificaciones y los puntos de vista, así como entre las diferentes líneas argumentativas. Estos hallazgos sugieren la necesidad de involucrar a los estudiantes en actividades que promuevan explícitamente procesos inferenciales y formas más complejas de estructuración del razonamiento. En consecuencia, el estudio propone la implementación de estrategias basadas en la mediación del razonamiento argumentativo como herramienta para el desarrollo del razonamiento causal, impulsando así la exploración de acciones orientadas a fortalecerlo.

Palabras clave

razonamiento; argumentación; educación; adolescencia

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Introduction

This article aims to establish connections between two extensively studied phenomena in education: causal reasoning and argumentation. Specifically, it focuses on analyzing the characteristics of causal reasoning exhibited by secondary school students when discussing socio-scientific topics conducted in a pedagogically extracurricular context, grounded in argumentation.

This study aims to explore argumentation as both a cognitive and an epistemic activity. It emphasizes the dialogic-discursive nature of argumentation, highlighting the inferential processes by which individuals critically evaluate information supporting a particular point of view. The acceptability of this information increases or decreases with the plausibility of the justifications provided, as previously demonstrated in the literature (Gaviria & Corredor, 2011; Gutiérrez, 2018; Kuhn, 2019; Shi, 2019; Solar Bezmalinovic et al., 2025). Such an understanding helps organize utterances into causal relationships or argumentative frameworks (Kuhn & Modrek, 2022; Walton & Macagno, 2016).

Although existing literature underscores the significance of argumentation in the formulation of explanations, models, and theories fundamental to constructing scientific knowledge (Erduran et al., 2015; Reznitskaya & Wilkinson, 2017) and in fostering cognitive and metacognitive skills (Cano et al., 2019; Rapanta, 2019), students continue to encounter difficulties with inferential processing and critical comprehension (Icfes, 2019; OECD, 2019). These difficulties negatively affect the development of scientific knowledge, as they constrain students' abilities to make informed decisions, thereby limiting progress and innovation across various scientific and technological fields.

Furthermore, the rapid evolution of technology and science requires individuals to possess an enhanced capacity to understand, evaluate, and effectively use scientific information. This underscores the importance of addressing students' difficulties in inferential processing and critical comprehension (National Research Council, 2012; National Science Board, 2020).

Given the significant role of argumentation in the construction of scientific knowledge, it is a fundamental resource for critically examining and evaluating ideas (Erduran *et al.*, 2015; Kuhn, 2019; Rapanta, 2019). Deploying argumentative skills, such as formulating hypotheses, presenting arguments and counterarguments, justifying claims, anticipating alternative perspectives, and managing evidence, enhances comprehension and facilitates the production of new knowledge (Macêdo et al., 2019). Previous research has demonstrated that

these skills contribute to reliable processes of understanding (Chen *et al*., 2021; Erduran *et al*., 2015; Salazar-Arbeláez *et al*., 2020).

In this regard, students are expected to develop reasoned predictions based on evidence about learning content and social phenomena. This capability enables them to articulate their ideas coherently, adopt informed positions, and make reasoned decisions (Jho *et al*., 2014; Jiménez-Leal & Gaviria, 2014; Sánchez-Castaño *et al*., 2015; Shi, 2019).

This article offers analytical tools to capture complex reasoning in natural contexts, such as classroom environments, by examining argumentation processes around socio-scientific topics relevant to secondary school students. Specifically, the objectives focus on identifying the causal lines employed, determining the relational levels of causality between explanatory hypotheses and their justifications, and examining causal relationships among the justifications themselves.

The following sections explore the relationship between argumentation and causal reasoning and provide empirical background, a methodological framework, results, discussion, and conclusions derived from this study.

Argumentation and Causal Reasoning

Argumentation is a dialogic activity that occurs in diverse contexts, characterized by a negotiation between the defense of one's own points of view and the consideration of opposing perspectives. Through this negotiation, the plausibility of particular points of view either increases or decreases (Asterhan & Schwarz, 2016; Erduran *et al*., 2015; Kuhn, 2019).

The discursive actions that characterize argumentation—such as justifying ideas and anticipating alternative and divergent positions—involve an inferential reasoning process. Through these processes, individuals critically review positions and reflect on the strengths, limitations, and potential of the arguments presented (their own or others'). Such reflection guides individuals towards possible responses aimed at convincing others, conceding a point, or maintaining a point of view (Kuhn & Dean, 2004; Ramírez-Roncancio, 2018).

Negotiation presupposes that thinking emerges within dialogic and discursive relationships and, as such, is constructed within specific sociohistorical contexts that enable the interpretation and shaping of surrounding realities (van der Veer, 1996; Vygotsky, 2000/1934). Language plays a crucial role in structuring thought by facilitating the transition from interpsychological to intrapsychological levels. Moreover, the socio-semiotic nature inherent to communicative exchanges with

the physical, symbolic, and social worlds significantly influences the construction of human cognition (Asterhan & Schwarz, 2016; Valsiner, 2007).

On the other hand, causal reasoning involves integrating events into structured representations of causal chains and networks (Gaviria & Corredor, 2011; Gutierrez, 2018; Jiménez-Leal & Gaviria, 2014). This cognitive ability has been examined from multiple perspectives, including perception and learning, reasoning and judgment, language, and social cognition (Holyoak & Cheng, 2011; Rips, 2011). These investigations examine individuals' cognitive development in both formal and informal educational contexts.

In this article, the organized representation of causal frameworks characteristic of causal reasoning is considered inherent to argumentative activity. This dialogical-discursive activity connects modes of utterance through deductive, inductive, and abductive causal relationships (Walton & Macagno, 2016), prompting epistemic revision as a core aspect of the demonstration process (Hennessy *et al*., 2023; Kuhn & Modrek, 2022; Reznitskaya & Wilkinson, 2017). Thus, presenting a justified viewpoint supported by diverse information—hypothetical, objective, or subjective—entails verifying causal hypotheses concerning phenomena in the surrounding world (Cano *et al*., 2019; Gutiérrez, 2017).

In argumentation, the dialogic process of linking empirical data to arguments facilitates the extraction of plausible inferences among points of view and justifications, thus enabling the support of refutations or counterarguments (Amaral & Leitão, 2019; Bender, 2020). In adolescents and adults, causal reasoning is shaped not only by formal educational experiences but also by previous knowledge and lived experiences. For instance, university students can identify covariations (relationships between two variables) as a result of their metacognitive skills and existing knowledge about causal structures (Jiménez-Leal & Gaviria, 2014), but they have difficulty in developing congruent, sufficient, and valid arguments and making rebuttals and counterarguments when they have not received specific training in argumentation strategies (Herrada-Valverde & Herrada-Valverde, 2024).

When evaluating the complexity of students' causal reasoning in an argumentative context, indicators such as relational causality and the connections between justifications and counterarguments are assessed. The level of causality, as conceptualized by Perkins and Grotzer (2005), is understood as a progression in cognitive complexity based on the structure and number of explanations offered for a given phenomenon. At the most basic level is simple linear causality, in which a single cause directly produces a consequence. At a more advanced level lies multiple linear causality, where several independent factors operate simultaneously to explain the phenomenon. The most complex

form is mediated causality, in which the phenomenon results from the interaction of multiple variables connected through a mediating factor that enables the relationship. This developmental sequence reflects a cognitive shift from linear and direct reasoning to increasingly integrated and mediated forms of causal thinking.

This typology is particularly relevant in educational contexts, as students' ability to recognize and articulate multiple or interrelated causes is associated with deeper scientific understanding (Perkins & Grotzer, 2005). Furthermore, as Jiménez-Leal (2014) suggest, individuals apply causal rules selectively based on prior knowledge, context, and cognitive resources, which may lead to linear, probabilistic, or correlational reasoning. In this line, Torres *et al*. (2022) emphasizes the importance of developing students' capacities to construct explanatory causal relationships in science education as a foundation for critical thinking and informed decision-making.

The relationship among justifications can be understood through criteria such as contiguity, covariation, and temporal order (Jiménez-Leal, 2014). Contiguity refers to the spatial and temporal proximity of the justifications; covariation implies that one justification influences another, with changes in magnitude and direction occurring simultaneously; and temporal order relates to the chronological sequence of justifications within a causal chain (Kuhn, 1991). In contrast, counter-argumentation involves presenting alternative explanations that support a given viewpoint while challenging the adequacy of an opposing argument (Amaral & Leitão, 2019).

Empirical Background

Interest in the study of causal argumentation has primarily focused on science education context, including physics, chemistry, biology, and mathematics (Gutiérrez, 2017; Salazar-Arbeláez *et al*., 2020; Shi, 2019; Solar, 2018). However, research on causal argumentation in other knowledge domains, such as history and language, has been less frequent (Amaral & Leitão, 2019; Castellanos & Navarro, 2020). These studies also examine the development of causal reasoning (Bender, 2020; Moshman, 2004) and its relationship with cognitive domains like language (Gärdenfors, 2021) and working memory (Shou & Smithson, 2014). Moreover, some investigations integrate causal explanations into the dialogic process of argumentation through evidence-based tests, experiments, and theoretical models (Gutiérrez, 2017; Jiménez & Díaz de Bustamante, 2003; Jiménez & Puig, 2010).

Causal reasoning is influenced by various factors, including individuals' prior experiences, their level of expertise, and metacognitive skills related to argumentation (Hernández-Rodríguez *et al*., 2024). Additionally, the type of task—oral or written discourse—and the conditions under which the task is performed—such as collaborative writing and specific instructional methods for producing arguments—also play a significant role (Gutiérrez Romero, 2019). For instance, simple cause-effect relationships tend to predominate in individual tasks (Jiménez & Díaz de Bustamante, 2003; Jiménez & Puig, 2010), whereas collaborative tasks facilitate more complex reasoning and generate a higher number of causal utterances (Gutiérrez, 2017).

Research on causal reasoning in the Colombian context has examined how pedagogical practices foster the development or enhancement of such reasoning among primary, secondary, and university students. Findings from these studies suggest that both direct instruction and instruction mediated by various tools can significantly enhance children's use of causal relationships, positively impacting their learning and facilitating transfer to other knowledge domains (Jin *et al*., 2021; Salazar-Arbeláez *et al*., 2020). For adults, studies have shown that causal reasoning is influenced by cognitive rules selectively applied according to context, prior knowledge, and probabilistic and metacognitive skills (Cano *et al*., 2019; Jiménez-Leal & Gaviria, 2014).

Methodology

A qualitative multiple-case study research design was used (Yin, 2018), situated within a naturalistic and realistic context, allowing the analysis of complex processes such as causal argumentation in classroom settings. At the analytical level, data triangulation was employed, combining dialogic-discursive analysis with comparative analyses based on specific evaluation criteria (Larrain & Moretti, 2011). This approach enabled the capture of the complexity inherent to argumentative processes within an ecological setting.

Participants

A total of 150 cases involving tenth-grade students from three public educational institutions in the central-eastern region of Colombia were intentionally selected. The sample comprised male (n = 48) and female (n = 102) students, with ages ranging from 15 to 18 years.

The inclusion criteria for case selection were as follows: a) students had to provide informed consent and assent, in accordance with Colombian

constitutional and legal regulations regarding the protection of personal data in psychological research (Resolution 8430 of 1993 from the Ministry of Health, Law 1581 of 2012, and Decree 1377 of 2013, the Deontological and Ethical Code of Psychologists); and b) participants were required to produce argumentative discourses, excluding cases in which the productions lacked an argumentative structure or were direct reproductions of arguments from other participants.

To ensure greater diversity and heterogeneity in the sample, cases were assigned to institutions proportionally based on the number of classes. Within each class, students were selected from the beginning, middle, and end of the official alphabetically ordered list, resulting in an average of eight to nine students per class.

Production context

The data corpus was constructed in a classroom setting designed to implement the Critical Debate Model (CDM), proposed by Leitão (2012). The CDM is a pedagogical tool that integrates critical discussion and collaborative construction to promote both the systematic development of argumentation skills and the appropriation of socio-scientific content. In this pedagogical experience, students were assigned to three distinct roles: (a) an investigative/evaluative group, responsible for introducing the topic, providing historical context, and evaluating the quality of arguments during the debate session; (b) a proposing group, tasked with initiating and defending arguments in favor of the debate topic; and (c) an opposing group, designated to present counterarguments in response to the topic under discussion.

The methodological cycle of the debate was structured into four distinct phases: (a) familiarization and contextualization with the debate topic; (b) preparation for the debate through training in argument identification, production, and evaluation competencies (Govier, 2014); (c) implementation of the critical debate session, carried out through structured and regulated stages designed to facilitate dialogic exchange between the proposing and opposing teams across five stages: closed debate, open debate, questioning, formulation of a plausible conclusion regarding the discussed controversy, and verdict; and (d) closure and feedback concerning the content discussed and the quality of argumentation. The cycle comprised between six and eight sessions, each lasting approximately 60 minutes and held once per week. Throughout these sessions, students debated controversial socio-scientific topics, such as “the pros and cons of legalizing recreational drug use”. Data were collected between 2019 and

2020, enabling the capture of argumentative reasoning within an ecological and collaborative setting.

The debate sessions were facilitated by final-year psychology undergraduates, who provided structured training in argumentation, including the differentiation between opinion and justified opinion, discursive markers, types of information, and evaluation criteria. Prior to implementation, these facilitators were trained by the project's researchers in argumentation skills and CDM.

Data Analysis

A dialogical-discursive approach was adopted, focusing on the causal structure of arguments and counterarguments within the argumentative productions of the selected corpus. Based on a rigorous theoretical review process, the following analytical categories (see Table 1) were defined to identify: causal lines (diversity of justifications and the ability to integrate evidence and perspectives); levels of causal relationships (complexity and depth of articulation between causes and effects); and the relationship between justifications and counterarguments (the manner in which ideas interconnect and reinforce each other, lending strength to a particular position).

The dialogical-discursive analysis complements these categories by capturing emergent aspects of discursive negotiation. This approach enables the assessment of the robustness and complexity of causal reasoning in the classroom and describes how it unfolds when addressing socio-scientific issues.

Table 1.
Analytic Categories

Categories	Description	Subcategories	Description	Indicators
Number of causal lines	This refers to the number and diversity of justifications offered to support a given viewpoint (Kuhn, 1991).	Simple	A justification (j) supporting the proposed viewpoint (p. v.) is provided.	The act of providing reasons or evidence to support a given viewpoint. The number of distinct justifications presented in support of a viewpoint. The range and variation of thematic content employed to construct and
		Multiple	Multiple justifications supporting the point of view (p. v.) were identified. These justifications may serve as parallel or alternative lines of reasoning.	

Categories	Description	Subcategories	Description	Indicators
				support the justification.
Levels of causal relationship between p. v and j. (Perkins & Grotzer, 2005)	Referring to the patterns of relationship established between cause and effect. The simplest form of this relationship is expressed as "A causes B".	Simple lineal causality (1)	The relationship between a p. v. and a j. follows a linear direction.	Presence or absence.
		Multiple lineal causality (2)	Relationship between a p. v. and multiple j., involving various explanatory lines—such as immediate, necessary, and sufficient causes, etc.	Presence or absence. Diversity of topics used in the justifications.
		Mediated cause (3)	At least three mediating agents (m) intervene in the effect of A on B. In this case, the influence of A on B occurs through m, which serves as a bridge establishing the causal connection between A and B.	Presence or absence of a cause that mediates the relationship established between p. v. and j.
Relationship between justifications (Cunningham & Kelley, 1973)	Referring to the relationships established among the different justifications that support the viewpoint. These relationships contribute to the coherence, strength, and solidity of the overall position.	Contiguity	It refers to the action of presenting one or more justifications in support of a p. v., in which the causes and effects are identified independently but are not interconnected.	It refers to the act of offering or listing justifications for a viewpoint that are not conceptually or causally related.
		Temporal sequence	It refers to the presence of one or more justifications arranged within a causal chain, with one preceding the other in temporal sequence. These relationships between justifications are characterized by "temporal precedence".	The action of offering justifications is organized in a causal chain. The action of offering justifications that precede others in terms of temporality.
		Covariation. Referring to the presence of	Correspondence (weaker level)	Co-occurrence between the justifications

Categories	Description	Subcategories	Description	Indicators
		one or more interrelated justifications that vary concomitantly in magnitude or direction, indicating a coordinated pattern of change (Kuhn, 1991).		The notion of co-occurrence implies concurrence in discourse, although the connections between the justifications are not explicitly developed.
			Covariation	The idea of covariation is explicit. Comparison (concerning the incidence of one justification over another) and quantification of that incidence (which can be implicit or explicit).
			Correlational change	A change in one justification co-occurs with a change in another justification. Co-occurrence of changes increases the probability that the change in one justification is responsible for a change in the other.
Counterargument (Amaral & Leitão, 2019; Kuhn, 1991)	Challenging the sufficiency or anticipated strength of your opponent's argument in relation to your argument. The validity of the ideas offered as support for a perspective is questioned.	Counterarguments involving causal necessity	They demonstrate that the antecedent (cause) is unnecessary for the result since the result can occur even in its absence, thereby weakening its causal role.	Opposition actions directed toward causal sufficiency.
		Discounting counterarguments	Can deny the existence of the supposed cause, dismissing it if it does not occur rather than proving there is no connection between	The action of totally denying the existence of the antecedent. The action of partially denying the existence of the antecedent.

Categories	Description	Subcategories	Description	Indicators
			the cause and the outcome.	
		Anticipation to a need or discounting	Action of anticipating and making explicit possible counterarguments (consequent, antecedent).	Incorporate elements of the opposing side in defense of one's viewpoint.
		Absence of counterargume nts	It refers to failing to generate an adverse argument.	No support for the opposing viewpoint. It is recorded when alternative theories are elaborated as if they were in opposition to the arguments.

Note: Own work

Procedure

The students' argumentative productions were examined through dialogic-discursive analysis (Larraín & Moretti, 2011), privileging the use of pre-established dialectical analytical categories present in the literature on causal reasoning. The examination of the productions followed three phases:

Pre-analysis: Situations with rich argumentative production were identified and selected, and the cases to be analyzed in this article were then refined for in-depth analysis.

Micro-analysis: Drawing on the analytic categories outlined in Table 1, the argumentative lines and causal relationships articulated in the production of arguments and counterarguments on the topic "Pros and cons of legalizing recreational drug use" were examined in detail. Subsequently, the micro-analysis was subjected to expert review, which reached consensus on the clarity, coherence, and precision of the applied analytic categories.

Macro-analysis: This stage involved identifying patterns emerging from micro-analyses and verifying them using descriptive statistical techniques.

Results

Vertical and horizontal microanalysis was performed to characterize the students' causal reasoning. The first aimed to establish a connection among different levels

of causal relationships between the point of view and the justifications. The second was to identify relationships among the justifications. In addition, counterarguments that reaffirmed or modulated the point of view were identified.

Levels of causal relationship between viewpoint and justifications

Overall, it was observed that two approaches emerged in structuring arguments in response to the question "What are the pros and cons of legalizing drugs for recreational purposes?" The first involved taking a position against (41.33%), in the middle (34%), or in favor (21.33%). The second involved presenting a list of arguments for and against (3.33%).

Furthermore, it was noted that many participants (81.3%) presented arguments with a multicausal structure, using diverse explanatory lines to support their stances on the topic. Those in favor constructed explanatory lines highlighting health benefits, reduced crime, and drug trafficking. For example, as Camila stated:

> I think it is good to legalize drugs because in other countries it has worked and has lowered the rates of drug addiction in adolescents, because many times things are only done to break the law and feel the adrenaline of being discovered. If they are made legal for recreation, this would not happen.

On the other hand, those against it mainly justified their stance by citing the rise in drug use and the health damage to both users and people around them. For example, Carolina said, "The legalization of drugs seems like a bad idea to me, since there would be more addicts addicted to it." However, it is essential to note that the information used was superficial, lacking evidence and data; rather, their responses were based on personal experiences or intuitive hypotheses. The need for more depth and development in the explanatory lines is evident.

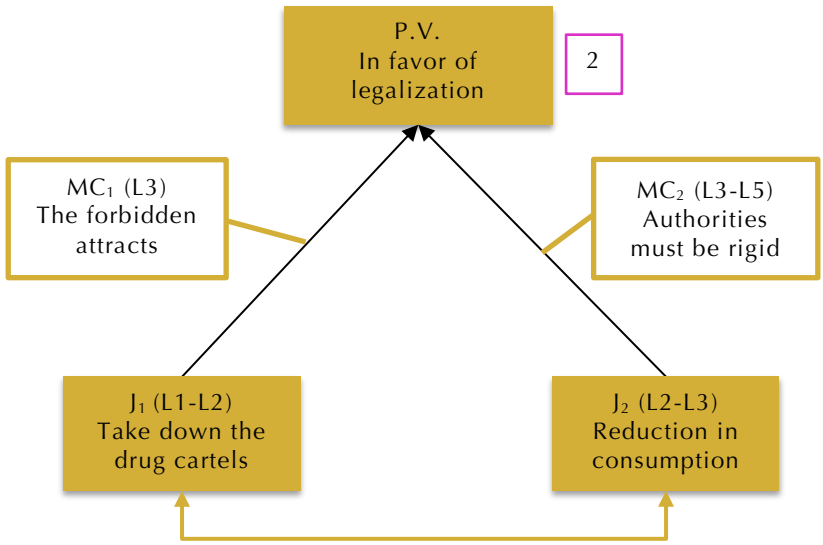
Regarding the causal relationships between the viewpoint and the justifications, the cases showed multiple linear structures (72.66%) and simple structures (19.33%), with a smaller proportion involving mediated causes (8.6%). Concerning multiple causality, the number of developed lines ranged from 2 to 8: 2 (46.6%), 3 (14%), 4 (6%), 5 (4.6%), and more than six lines (4%). One case that illustrated multicausality and mediation was case 34:

Dilemma: What are the pros and cons of legalizing drugs for recreational purposes?
Subject: N.° 34 Pseudonym: Catalina

L1 My opinion on this is that when the minimum dose is legalized for recreational
L2 purposes, it could end with many cartels that are dedicated to the production of this
L3 and in a certain way, there could be a reduction in consumption since what is
L4 prohibited is what is most desired: it is worth clarifying that the authorities must be
L5 very strict with this issue, if it is a minimum dose, not one gram more.

Catalina presented a case of multiple relational causality, supported by two justifications: the dismantling of drug cartels and the reduction of consumption (see Figure 1). In the first justification, J1 (L1-2), a mediating because links the position to the claim, suggesting that prohibition contributes to increased trafficking. Therefore, lifting the ban could lead to a reduction in such activity. In the second justification, J_2 (L2-3), the anticipated reduction in consumption is conditional—legalization alone is insufficient unless accompanied by "strict" enforcement by authorities, which is presented as a necessary condition for the outcome to occur.

Figure 1.
Argumentative diagram Case No. 34



Note: P.V. = point of view; MC = mediated cause. Covariation with correlative change = ←→. Square with number inside = Multiple Causality.

A direct covariation between the justifications was identified. It was found that between J_1 and J_2, there is a direct covariation with a correlational change. Specifically, the reasoning suggests that if drugs are no longer prohibited, the drug cartels would cease to exist, leading to a subsequent decrease in consumption.

Relationships between justifications

Most participants constructed multicausal arguments, with slight variations in the types of relationships among the justifications provided. These relationships were primarily based on structures of covariation (67.3%), followed by contiguity (46%), and temporal order (18.6%). Regarding the nature of these connections, 34.6% were correspondence relationships, 19.3% were explicit covariation, and a smaller proportion, 13.3%, reflected correlational changes.

In this sense, students' reasoning focused on strengthening their arguments by establishing connections among justifications, with one justification influencing or reinforcing another. This reflects covariation relationships, as observed, for example, in the case of subject 6 (S6):

Dilemma: What are the pros and cons of legalizing drugs for recreational purposes?

Subject: N.° 6 Pseudonym: Clara

L1 What do I think about the legalization of drugs?

L2 It is good as long as it helps people and up to a certain amount. Still, if this is used in a bad

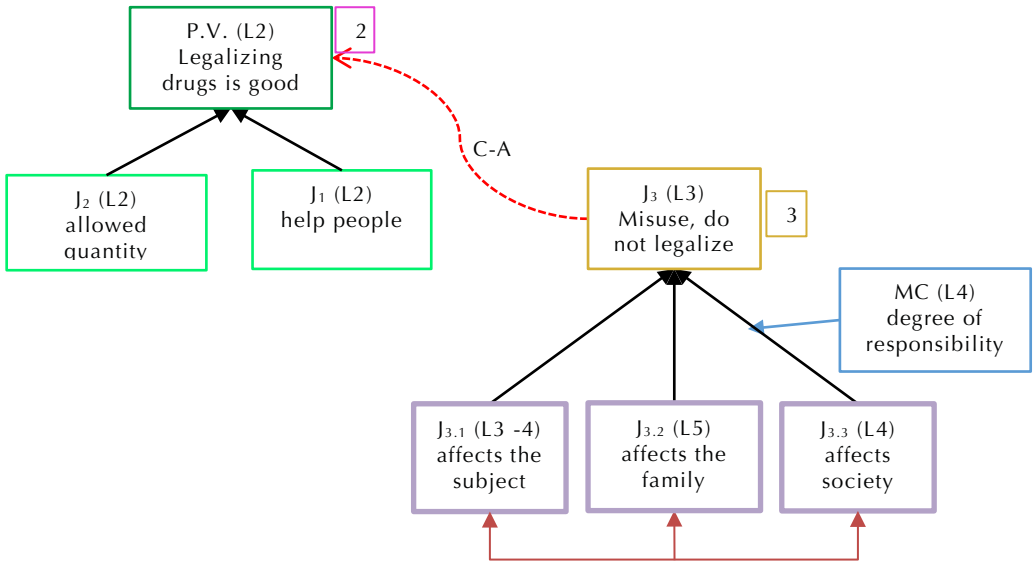
L3 way, it should not be made legal because this would affect both the life of a person, as well

L4 as society, since it does not show responsibility in this, and it can affect the rest of the

L5 people or families that are involved in this.

Clara presents a case of multiple linear causality, supported by three justifications: "helping people, allowed amount, and misuse" (see Figure 2). In justifications J_3, a direct covariation relationship was observed, as the reasons provided—namely, increased harm to individuals, families, and society—intensified in the same direction. Additionally, a correspondence covariation was identified among these justifications due to their co-occurrence. This co-occurrence was not explicitly elaborated in the student's discourse.

Figure 2.
Argumentative Framework Case No. 6



Note: P. V. = point of view; C-A, red dotted line = Counterargument. MC = mediated cause. Covariation with correlated change = ↔. Purple box with a number inside = Multiple causality.

In the educational institution whose social context more closely aligns with situations of spam consumption, a greater presence of covariation relationships was observed. Students in this context, drawing on their sociocultural experience, formulated causal reasoning that extends beyond individual consequences to include impacts on families and society. Additionally, in this setting, correlational patterns emerged that, according to the taxonomy of causal reasoning, reflect more sophisticated features in students' causal explanatory processes.

Counter-argumentation

During the analysis of students' explanations, researchers identified that only 37 students (24.6%) produced counterarguments of various types. Of these, 17 students (11.3%) presented discounting counterarguments, five students (3.3%) used necessity counterarguments, and 14 students (9.3%) incorporated both necessity and discounting forms. Additionally, only one student (0.6%) included elements related to counter-argumentation, although these did not constitute a complete counterargument.

These findings indicate that only a subset of students incorporates counterarguments to strengthen their viewpoints or reinforce their justifications.

Moreover, when counterarguments are used, they often anticipate potential consequences that either relativize or reinforce the initial position. For instance, in the case of student 131, the counterargument serves to relativize their viewpoint, reflecting a more nuanced approach to the issue under discussion.

Dilemma: What are the pros and cons of legalizing drugs for recreational purposes?

Subject: N.° 131 Pseudonym: Luis

L1 Well, I think it's a bad thing because now everyone would have access to these things, and I

L2 also think that cases of addiction and consumption by minors would increase. However, if

L3 authorities legalized them, they could eliminate the drug cartels and, in turn, reduce the

L4 violence.

Luis presented a multicausal explanation to support his view that drug legalization is harmful, offering three justifications. (J_1) an increase in addiction cases; (J_2) a rise in addiction cases, and (J_3) greater consumption among minors. However, he introduced a counterargument using the discourse marker "although," which partially challenged his initial claim by acknowledging potential benefits of legalization—specifically, the reduction of drug trafficking and associated violence. This reasoning reflects cognitive flexibility, as Luis anticipated alternative outcomes and modulated his position with coherent and plausible justifications. Rather than presenting a rigid stance, he integrated contrasting perspectives, enhancing the depth and nuance of his argumentation.

In case S73, the counterargument served to reaffirm their initial point of view.

Dilemma: What are the pros and cons of legalizing drugs for recreational purposes?

Subject: N.° 73 Pseudonym: Fabiola

L1 I do not agree with the legalization of drugs because if that happens all the people will

L2 become addicted. Everything would change quite a bit in everything because those same

L3 drugs make us lazy. I wouldn't want them to legalize it because it would negatively impact

L4 our physical and psychological health. Additionally, I don't think it's right that, if legalized,

L5 it could be consumed anywhere. I do not judge people who consume all types of drugs but

L6 in my point of view, I do not agree with legalization.

Fabiola presented a multicausal argument against the legalization of drugs, supported by five justifications: (J1) increased addiction rates, (J2) negative personal changes, (J3) limited medicinal applications, (J4) physical and psychological harm, and (J5) unrestricted consumption. Throughout her argumentation, she anticipated two potential counterarguments. In J_3, she acknowledged medicinal uses but reaffirmed her opposition, reinforcing her stance (L3). In J_5, addressing unrestricted consumption, she anticipated the moral judgment of users and concluded with a responsive move (L6) that reiterated her original viewpoint. In both instances, anticipating counterarguments reinforced her position: "I disagree with the legalization of drugs." By pre-emptively addressing potential benefits and highlighting associated harms, she expanded her reasoning to include additional consequences for individuals' functioning and physical and mental health.

Conclusions

The results of this study provide a space for reflection on the complexity of constructing solid and coherent arguments (*cogency*) in socio-scientific topics such as "the legalization of drugs for recreational purposes," which are not part of the curriculum.

The analysis shows that most participants construct multicausal arguments with slight variations in the relationships between the justifications, based on contiguity, temporal order, and covariation structures. Researchers explain these findings through inferential systems, highlighting the ability to use contextual evidence and to construct multiple causal relationships (Jiménez-Leal & Gaviria, 2014; Kuhn & Dean, 2004; Navarro-Roldán *et al*., 2020).Likewise, a superficial understanding is evident in how information types are used to support the arguments produced (Chen *et al*., 2021). This understanding is characterized by arguments that are close to everyday contexts, with unique points of view, dispensing with analogies, and relying on examples from personal experience (Cano *et al*., 2019). This result highlights the need for educational interventions that emphasize the use of reliable, plausible, and broad information to build academic knowledge. These findings reinforce the idea that causal reasoning in

argumentative contexts requires training and that educational objectives should foster an understanding of what it means to engage in inferential activities that require continuous revision and complex forms of structuring reasoning (Jin *et al*., 2021; Jiménez-Leal & Gaviria, 2014). Regarding counterarguments, researchers observe a limited use, mainly to reaffirm an initial position. This result may be due to: i) the use of argumentative schemes similar to those used in natural contexts (Asterhan & Schwarz, 2016; Cano *et al*., 2019); ii) difficulties in using anticipatory thinking to visualize possible consequences and to articulate a point of view (Herrada-Valverde & Herrada-Valverde, 2024; Kuhn & Modrek, 2022); iii) the nature of the topic, which may introduce biases in the understanding of socio-scientific problems given its proximity to participants' beliefs or ideologies (Gutiérrez Romero, 2019; Ramírez-Roncancio, 2018); and iv) the learning situation, which includes instruction, the sociohistorical context, and the facilitator's mediation, aspects that are interrelated in understanding the construction of knowledge (Valsiner, 2007; Vygotsky, 2000/1934).

Consequently, future research could explore the role of the mediator in improving argumentative skills. Moreover, in the context of this research, the difficulty in generating counterarguments can be explained, in part, by the predominance of traditional teaching approaches. These approaches tend to assign students a passive role, focused on following classroom rules, rather than encouraging critical thinking and the active construction of knowledge. In addition, traditional teaching tends to validate knowledge uncritically, limiting opportunities to question ideas or develop argumentative skills. Added to this is the scarcity of spaces for debate where students can confront different perspectives and interact with others, which hinders the practice and use of argumentative strategies.

When counterarguments appear, researchers can identify two possible interpretations: one less dialogic and discursive, related to the instructional process, and another that arises from the producer's genuine anticipation, implying a higher level of reflexivity and complexity of thought (Hernández-Rodríguez *et al*., 2024; Jiménez-Leal & Gaviria, 2014; Kuhn, 2019; Ramírez-Roncancio, 2018).This study enriches the discussion on causal reasoning skills and their importance in constructing solid and coherent arguments (*cogent*) on socio-scientific topics. In this regard, the results support the proposals of educational psychology that promote research, discovery, and argumentation activities in context, as opposed to more directive approaches focused on the teacher's role in the instructional process (Leitão, 2012; Macêdo *et al*., 2019; Rapanta, 2018). Additionally, it is essential to have argumentation-rich instructional scenarios that allow for the transfer of competencies such as evidence evaluation, metacognitive reflection, explanation, and anticipation to

different domains of activity (Gaviria & Corredor, 2011; Hernández-Rodríguez *et al*., 2024; Reznitskaya, & Wilkinson, 2017).

This study acknowledged the vital role of questions in prompting students to anticipate evidence for and against a particular argument. This dialogic action promotes multicausal reasoning, flexible thinking, questioning of everyday experiences, and the construction of evidence-based arguments. Thus, the use of reflective questions can be a methodological resource that cognitively challenges students and helps develop argumentative skills such as flexibility, anticipation, revision, and evaluation of positions (Castellanos *et al*., 2020; Gutiérrez, 2018; Rapanta, 2018).It is essential to discuss how to improve causal reasoning skills in the school context, especially in socio-scientific topics such as the legalization of drugs for recreational purposes. Exploring which strategies and tools can support this purpose is also relevant. The results indicate that argumentation contexts in which students discuss socio-scientific topics promote the construction of positions, revealing processes such as epistemic review of the phenomenon (i.e., where it comes from, which common beliefs and concepts are associated, what evidence supports the stance, what information is known and needs further exploration), negotiation and decision-making. These dialogical actions promote forms of understanding and citizen participation that contribute to addressing issues present in the social environment (Gutiérrez, 2018; Jho *et al*., 2014; Ramírez-Roncancio, 2018).

In summary, participation in dialogical activities and scenarios promotes the emergence of processes such as anticipation, evidence evaluation (review), counter-argumentation, and the construction of multicausal explanations. These processes serve as tools for constructing knowledge through epistemic vigilance regarding the beliefs and information we, as citizens, hold about social and political issues. This study does not examine the evolution of argumentative skills over time or the effects of participation in socio-scientific debates, using questions that probe students' causal reasoning. Future research should consider asking subjects questions to broaden or deepen the evidence presented and to assess how they perceive their progress in relation to their argumentative skills, thereby providing pedagogical support in the classroom. Likewise, it is suggested that changes in causal reasoning skills in argumentation contexts be analyzed after receiving some intervention or training.

This study offers valuable implications for both research in educational psychology and teaching practice in school settings. In particular, it highlights the importance of analyzing how personal beliefs, ideologies, and prior knowledge influence the construction of arguments and counterarguments on socio-scientific topics. It also highlights the need to design training programs that equip teachers

to argue and to use argumentation-based pedagogical strategies to strengthen students' reasoning.

In addition, this study provides a framework that values active participation in debates about relevant social issues. Such debates not only facilitate the confrontation and review of different points of view but also favor the construction of coherent, evidence-based arguments. These strategies enable students to adopt informed and critical stances on social issues, thus promoting the development of active and reflective citizenship.

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