

Executive functions and cognitive load: a classroom-based experience with ENEM items

ABSTRACT

This study analyses how the reduction of extraneous cognitive load influences the mobilisation of Executive Functions in solving mathematical tasks in a school context. Grounded in the articulation between the Executive Functions model—Working Memory, Inhibitory Control, and Cognitive Flexibility—and Cognitive Load Theory, the study seeks to understand the cognitive processes involved during task resolution. The research adopts a qualitative interpretative approach and was conducted with 19 high school students (2nd year) from a public school. Data were generated through the resolution of five ENEM items on linear functions, presented in two versions: original and modified, with reduced extraneous cognitive load achieved through linguistic simplification, elimination of redundancies, and textual reorganisation. Data collection occurred in three stages: individual resolution, group discussion, and whole-class discussion. The results indicate that reducing extraneous cognitive load does not alter the conceptual nature of the tasks but modifies the cognitive conditions under which they are solved. Greater fluency in problem-solving processes, improved organization of information, and a reduced need for active filtering were observed in the simplified versions. Additionally, the mobilisation of Executive Functions was found to be sensitive to task structure, being influenced by the way information is presented. The study contributes by making explicit the cognitive mechanisms underlying the relationship between item structure and mathematical problem solving, advancing the articulation between Cognitive Load Theory and Executive Functions, and highlighting the role of cognitive conditions in mathematics learning.

KEYWORDS: Executive Functions; Cognitive Load Theory; ENEM; Assessment; High School.

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Funções executivas e carga cognitiva: uma experiência em sala de aula com questões do ENEM

RESUMO

Este estudo analisa como a redução da carga cognitiva extrínseca influencia a mobilização das Funções Executivas na resolução de tarefas matemáticas em contexto escolar. Fundamentado na articulação entre o modelo das Funções Executivas — Memória de Trabalho, Controle Inibitório e Flexibilidade Cognitiva — e a Teoria da Carga Cognitiva, o trabalho busca compreender os processos cognitivos mobilizados durante a resolução de tarefas. A pesquisa, de abordagem qualitativa interpretativa, foi realizada com 19 estudantes da 2ª série do Ensino Médio de uma escola pública. Os dados foram produzidos a partir da resolução de cinco questões do ENEM sobre função afim, apresentadas em duas versões: original e modificada, com redução da carga cognitiva extrínseca por meio de simplificação linguística, eliminação de redundâncias e reorganização textual. A coleta ocorreu em três momentos: resolução individual, discussão em grupo e discussão coletiva. Os resultados indicam que a redução da carga cognitiva extrínseca não altera a natureza conceitual das tarefas, mas modifica as condições cognitivas de sua resolução. Observou-se maior fluidez nos processos, melhor organização das informações e menor necessidade de filtragem ativa em enunciados reduzidos. Evidenciou-se, ainda, que a mobilização das Funções Executivas é sensível à estrutura das tarefas, sendo influenciada pela forma de apresentação das informações. O estudo contribui ao explicitar os mecanismos cognitivos envolvidos na relação entre estrutura dos itens e resolução matemática, avançando na articulação entre Teoria da Carga Cognitiva e Funções Executivas, e destacando o papel das condições cognitivas na aprendizagem matemática.

PALAVRAS-CHAVE: Funções Executivas; Teoria da Carga Cognitiva; ENEM; Avaliação; Ensino Médio.

INTRODUCTION

Large-scale external assessments, such as the Brazilian National High School Examination (Exame Nacional do Ensino Médio – ENEM), play a structuring role in the Brazilian educational landscape, influencing teaching practices, curriculum organisation, and teaching and learning processes. However, students' performance in these assessments cannot be explained exclusively by their conceptual mastery of mathematical content. Item structure, textual organisation, and the cognitive demands imposed by the tasks that comprise the examination are variables that affect students' performance.

In this context, two theoretical frameworks have proved particularly relevant: the Executive Functions (EFs) model and Cognitive Load Theory (CLT). Executive Functions are defined as a set of self-regulatory cognitive abilities that enable individuals to control impulses, adapt their behaviour, make decisions, and solve goal-directed problems. They are recruited whenever individuals undertake tasks that have not become automated, as is often the case in mathematics learning.

The model proposed by Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000) identifies three core components of Executive Functions: Working Memory (WM), Inhibitory Control (IC), and Cognitive Flexibility (CF). These components operate in a partially independent yet interrelated manner and are particularly important in tasks involving multiple stages, the reorganisation of information, and the need for strategic adaptation.

Working Memory is responsible for the temporary maintenance and manipulation of information required to achieve a goal. As Diamond (2013) points out, it can operate on verbal, visuospatial, or multimodal content and is crucial in situations requiring the simultaneous co-ordination of information, such as solving contextualised mathematical problems. Inhibitory Control, in turn, refers to the ability to suppress automatic or irrelevant responses, thereby enabling the selection of relevant information. Cognitive Flexibility is associated with the ability to switch between strategies or perspectives when faced with obstacles.

Within the domain of Executive Functions, in addition to their basic components — Working Memory, Inhibitory Control, and Cognitive Flexibility — there are higher-order processes related to the monitoring and regulation of cognitive activity. Among these processes, metacognition has been identified as a relevant construct for understanding learning, particularly in mathematics, as it involves individuals' ability to monitor, assess, and adjust their own ways of thinking while solving tasks. Studies in this field (Rosa & Schmitz, 2020) also indicate the predominance of qualitative approaches and the central role of the analysis of cognitive strategies, reinforcing the importance of research that considers not only task outcomes but also the processes involved in solving them.

Cognitive Load Theory, developed by Sweller (1988; 2003; 2023), is based on the assumption that working memory has a limited capacity. When the demands of a task exceed this capacity, cognitive overload occurs, impairing performance and learning. CLT distinguishes three types of load: intrinsic load, which is related to the complexity of the content; extraneous load, which results from the way information is presented; and germane load, which is associated with the effort devoted to constructing cognitive schemas.

In the case of ENEM items, the presence of lengthy texts, dispersed contextual information, and irrelevant data may increase extraneous cognitive load, requiring greater recruitment of Working Memory and Inhibitory Control. Students may therefore experience difficulties not only because of limitations in their conceptual knowledge but also because of the overload resulting from the organisation of the item wording.

From a pedagogical perspective, studies grounded in Universal Design and Universal Design for Learning have highlighted the importance of the way tasks are presented in promoting access to learning, advocating that information be organised clearly, systematically, and accessibly (Cassano, Muzzio & Góes, 2022). Although these approaches are not directly grounded in cognitive models, they converge with Cognitive Load Theory by emphasising the reduction of unnecessary barriers to information processing.

Despite the relevance of these frameworks, empirical studies that directly relate the recruitment of Executive Functions to different levels of cognitive load in basic education classroom settings remain scarce. In this regard, studies such as those by Braga and Dalto (2025) and Cunha and Dalto (2025) address Executive Functions in isolation, while the study by Chagas (2019) similarly addresses Cognitive Load Theory in isolation.

In mathematics education, problem solving constitutes one of the field's core organising principles and is understood not only as a teaching strategy but also as an object of inquiry into the processes recruited by students when faced with mathematical tasks (Onuchic & Allevato, 2011). From this perspective, understanding how the structural characteristics of tasks influence these processes may contribute to enriching the interpretations developed within the field. Moreover, despite a longstanding tradition of research on problem solving, the comprehension of problem statements, and solution strategies in mathematics education, studies grounded in Executive Functions and Cognitive Load Theory may contribute to understanding the cognitive mechanisms underlying these processes, thereby extending the interpretations traditionally developed within the field.

In view of this gap, this article draws on part of Paula's (2026) dissertation, which aimed to analyse the effects of reducing extraneous cognitive load on the recruitment of Executive Functions — Working Memory, Inhibitory Control, and Cognitive Flexibility — as students in the second year of upper secondary school solved five ENEM questions involving first-degree polynomial functions.

By integrating the model proposed by Miyake et al. (2000) with Sweller's Cognitive Load Theory (1988; 2003), the aim is to understand not only the final outcomes of the problem-solving process but also the cognitive processes recruited while the activity is carried out in authentic classroom settings.

THEORETICAL FRAMEWORK

The theoretical framework of this study is organised into two complementary strands. The first addresses Executive Functions, understood as cognitive processes responsible for regulating thought and action in situations requiring planning, attentional control, and strategic adaptation (Miyake et al., 2000; Diamond, 2013). The second presents Cognitive Load Theory, which explains how the

structural characteristics of a task influence the use of working-memory resources (Sweller, 1988; 2003). Each of these strands is presented systematically below.

EXECUTIVE FUNCTIONS

Executive Functions (EFs) constitute a set of higher-order cognitive processes responsible for the intentional regulation of behaviour, particularly in novel situations or those requiring deliberate control. Unlike automated responses, EFs are recruited when individuals need to plan, monitor, adjust strategies, or inhibit impulses in response to complex demands, as frequently occurs when solving mathematical tasks.

The model proposed by Miyake et al. (2000) has become one of the main references for the structural delineation of EFs. Based on factor analyses, the authors identified three core components that are partially independent yet interrelated: Working Memory (WM), Inhibitory Control (IC), and Cognitive Flexibility (Shifting). This tripartite structure makes it possible to understand both the specificity and the functional integration of executive processes.

Working Memory (WM) refers to the ability to maintain and manipulate information temporarily in pursuit of a goal. According to Diamond (2013), it is an active system that not only stores information but also reorganises and transforms it according to task demands. WM may operate on verbal, visuospatial, or multimodal content and is essential for co-ordinating multiple representations simultaneously. When solving ENEM questions involving affine functions, for example, students must retain numerical data, interpret relationships between variables, and integrate this information with the corresponding algebraic structure. When the item statement is lengthy or presents dispersed information, the demand placed on WM tends to increase, potentially impairing progress towards a solution.

Inhibitory Control (IC) corresponds to the ability to suppress impulsive responses or irrelevant information. According to Diamond (2013), IC is essential for maintaining attentional focus and preventing distracting stimuli from interfering with the main task. In contextualised problems, such as those found in ENEM, students frequently encounter lengthy narratives containing supplementary information. An inability to inhibit secondary information may lead to the inappropriate use of numerical data or to a mistaken interpretation of the problem situation. IC therefore acts as a filtering mechanism, enabling the selection of mathematically relevant elements.

Cognitive Flexibility (CF), in turn, refers to the ability to switch perspectives, reformulate strategies, and adapt when faced with obstacles. Miyake et al. (2000) emphasise that shifting entails switching between different mental sets, thereby enabling strategic reorganisation. In mathematical tasks, CF is recruited when students abandon a procedure that does not lead to a solution and adopt a different approach, such as rearranging an equation, reinterpreting a variable, or re-considering the functional structure of the problem.

It is important to emphasise that these three components do not operate in isolation. When solving a contextualised mathematical task, WM keeps information active, IC filters what is relevant, and CF enables strategic adjustments when necessary. The interaction among these processes becomes particularly evident in

tasks requiring careful reading, data interpretation, and the integration of symbolic representations.

Several empirical studies have demonstrated consistent relationships between Executive Functions and mathematical performance throughout schooling (Blair & McKinnon, 2016; Santana, Roazzi, Melo, Mascarenhas, & Souza, 2019; Santana, Roazzi & Melo, 2020; Gilmore, Simsek, Eaves, & Cragg, 2024). These findings indicate that individual differences in executive functioning may help explain why students with similar levels of mathematical knowledge perform differently when faced with apparently equivalent tasks.

In the context of this study, it is assumed that different levels of cognitive load may alter the conditions under which these functions are recruited. When textual organisation imposes excessive demands, Working Memory may become overloaded, Inhibitory Control may prove insufficient to filter information, and Cognitive Flexibility may be impaired when difficulties arise. Understanding how EFs are recruited in authentic classroom situations therefore contributes to the analysis not only of students' final performance but also of the cognitive processes involved in solving mathematical tasks.

COGNITIVE LOAD THEORY

Cognitive Load Theory (CLT), developed by Sweller (1988) and subsequently expanded (Sweller, 2003, 2023), is grounded in human cognitive architecture, particularly the limited capacity of working memory and the comparatively enduring nature of long-term memory. According to this framework, learning and performance are influenced by the amount of mental effort required by a task.

Sweller (1988) argues that working memory has a limited capacity in terms of both duration and the number of elements that can be processed simultaneously. When the complexity of a task exceeds this capacity, cognitive overload occurs, impairing the efficient processing of information.

CLT distinguishes among three types of cognitive load:

- a) intrinsic load, related to the inherent complexity of the content and the interactivity among its elements;
- b) extraneous load, resulting from the way information is presented;
- c) germane load, associated with the effort devoted to the construction and automation of schemas.

Intrinsic load depends on the number of interrelated elements that must be processed simultaneously. In the case of first-degree polynomial functions, for example, understanding the relationships among variables and coefficients and interpreting them within a given context may involve a high level of element interactivity, particularly for students with limited conceptual knowledge.

Extraneous load, in turn, is not related to the content itself but to how it is presented. Lengthy texts, redundant information, a lack of visual emphasis, or inadequate organisation may unnecessarily increase the demands placed on working memory. Sweller (2003) emphasises that instruction should seek to

minimise extraneous load, thereby allowing cognitive resources to be directed towards schema construction.

Germane load refers to the productive effort devoted to learning, when cognitive resources are invested in organising and integrating knowledge. Unlike extraneous load, germane load is desirable.

Within mathematics education, studies have shown that the structure of assessment items directly influences extraneous cognitive load. In this context, Chagas (2019) investigated the effects of reducing extraneous cognitive load in ENEM mathematics items through an empirical study involving 691 students across eight locations. To this end, 24 items administered between 2010 and 2015 were selected, and modified versions of each were produced. Four assessment instruments were then constructed, containing different proportions of original and reduced-load items. These instruments were balanced in terms of difficulty and administered under conditions similar to those of the examination, with controlled completion times and a socio-economic questionnaire.

The quantitative analysis, based on a comparison of correct-response rates, indicated that reducing extraneous cognitive load improved performance on some items (six), although it reduced performance on others (two), suggesting that its effects are not uniform. In addition, this reduction was generally more beneficial to female students, helping to narrow performance differences that had previously favoured male students. Evidence of associations with socio-economic variables, such as parental educational attainment and family income, was also observed. The study concludes that the way items are constructed has a significant impact on students' performance, indicating that structural and presentational aspects of questions may be decisive, particularly given ENEM's role as the main route of access to higher education in Brazil (Chagas, 2019).

Different strategies have been proposed for reducing extraneous cognitive load, with the aim of making tasks more accessible without altering their conceptual complexity. Among these are the techniques systematised by Gillmor, Poggio and Embretson (2015), which provide a set of principles for designing and adapting items so that they impose fewer unnecessary cognitive demands.

One such technique is translation or linguistic simplification, which consists of reducing the syntactic complexity of the item wording by using more direct structures and more accessible vocabulary. This strategy seeks to reduce the effort required for reading, allowing cognitive resources to be directed towards mathematical understanding. Another widely discussed technique is the elimination of irrelevant information, which involves removing contextual elements that do not contribute directly to solving the problem. According to Gillmor, Poggio and Embretson (2015), the presence of superfluous information may increase the load placed on working memory and require greater recruitment of filtering processes, making it more difficult to identify the essential information.

Signalling is another relevant strategy and consists of highlighting important information through visual or structural features, such as bold type, markers, or organisation into stages. This technique directs students' attention and reduces the need to search actively for relevant information. The visual and aesthetic organisation of the item wording also plays a significant role in reducing extraneous load. Statements with a clear structure, appropriate segmentation, and a

balanced distribution of information tend to require less cognitive effort than those presented in a dense or disorganised manner.

The sequencing of information refers to presenting data in a logical and progressive order aligned with the anticipated solution process. When information is presented in a disordered manner, students must reorganise it mentally, increasing the load placed on working memory. In addition, the use of visual aids, such as tables, graphs, and diagrams, can help externalise part of the cognitive processing, reducing the need to maintain multiple elements simultaneously in working memory. Finally, numerical simplicity is a strategy intended to avoid unnecessarily complex calculations, enabling the task to remain focused on the mathematical concepts involved rather than on arithmetic operations that may increase cognitive load without contributing to learning.

As discussed by Gillmor, Poggio and Embretson (2015), these techniques share the principle that the way information is presented directly influences the cognitive effort required by a task. Reducing extraneous cognitive load is intended to free working-memory resources, thereby supporting the processing of conceptual relationships and the construction of schemas.

THE INTERRELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS AND COGNITIVE LOAD

Integrating Executive Functions (EFs) and Cognitive Load Theory (CLT) makes it possible to understand how the structural demands of tasks influence the recruitment of the cognitive processes involved in solving mathematical problems. Whereas CLT emphasises the limitations of working memory and the effects of different types of cognitive load on performance (Sweller, 1988; 2003; 2023), the EF model extends this analysis by considering mechanisms of control, regulation, and strategic adaptation (Miyake et al., 2000; Diamond, 2013). This integration enables the interpretation not only of the amount of cognitive effort involved but also of how individuals manage this effort.

In this context, recent evidence has indicated that Executive Functions play a central role not only in supporting mathematical reasoning but also in mediating interactions between students and the structure of tasks. Dalto (in press), in a study involving undergraduate mathematics teacher education students, proposed an integrated analysis of performance, perceived mental effort, and executive functioning while participants solved ENEM questions presented in versions with different levels of extraneous cognitive load. The study combined standardised instruments for assessing Executive Functions — encompassing Working Memory, Inhibitory Control, and Cognitive Flexibility — with mathematical tasks presented in versions that differed in their textual structure, thereby enabling comparisons among objective performance, solution time, and subjective indicators of effort and difficulty.

The results showed that the level of Executive Function development was directly associated with how students responded to structural variations in the items. Participants who performed less well on tests of executive functioning showed greater vulnerability to extraneous cognitive load, as evidenced by lower correct-response rates and higher levels of perceived mental effort when faced

with lengthier or less well-organised item statements. By contrast, students with better executive functioning showed greater stability in response to these variations and were able to maintain more consistent levels of performance, even under conditions of greater cognitive demand.

These findings reinforce the proposition that the recruitment of EFs — particularly Working Memory, Inhibitory Control, and Cognitive Flexibility — is directly related to the ability to manage external task demands, such as selecting relevant information, inhibiting distracting elements, and reorganising data presented in a dispersed manner. When extraneous cognitive load is high, Working Memory may become overloaded, reducing the capacity to retain and manipulate information essential to solving the problem. At the same time, greater demands are placed on Inhibitory Control to filter out irrelevant information, while Cognitive Flexibility may be impaired, particularly when students remain anchored to inappropriate initial interpretations or are unable to reorganise the structure of the problem.

Conversely, reducing extraneous cognitive load does not alter the conceptual complexity of the task — that is, its intrinsic load — but modifies the conditions under which Executive Functions are recruited. Reorganising the presentation of information, eliminating redundancies, and making relevant relationships more explicit create a more cognitively favourable environment in which executive resources can be directed more efficiently towards mathematical problem solving. Such reorganisation is likely to be particularly beneficial to students with less developed executive functioning, as it reduces the additional demands for cognitive control and management imposed by the structure of the item statement.

METHODOLOGICAL PROCEDURES

This investigation is characterised as a qualitative study, as proposed by Bogdan and Biklen (1994), aimed at understanding the cognitive processes recruited by students while solving mathematical tasks. This methodological choice is grounded in the view that the phenomenon under investigation — the recruitment of Executive Functions in problem-solving situations — cannot be adequately captured through exclusively quantitative indicators. It therefore requires an analysis of the meanings participants attribute to the situations presented and of the strategies they develop throughout the activity.

The research was conducted in a classroom setting, which constituted the natural context of the investigation, and one of the researchers also served as the class teacher. This dual role made it possible to follow the students' solution processes closely and to understand how they interacted with the tasks over time. The participants were 19 students in the second year of full-time upper secondary education at a state school in Londrina, Paraná, Brazil. The study was approved by the UTFPR Research Ethics Committee for Studies Involving Human Participants (CAAE 82569924.3.0000.0165).

The mathematical content addressed was the first-degree polynomial function, selected because it was included in the curriculum planned for that period and frequently appears in large-scale assessments such as ENEM. Data were collected using two instruments comprising five ENEM questions, each presented in two versions: an original version and a modified version in which extraneous

cognitive load had been reduced. The modifications were based on strategies described in the literature, particularly those systematised by Gillmor, Poggio and Embretson (2015), including linguistic simplification, the elimination of redundant information, and the structural reorganisation of item statements.

The instruments were developed through an analysis of ENEM papers administered between 2009 and 2024, including different administrations of the examination (first, second, and third), with the aim of identifying questions involving affine functions that could potentially undergo a process of extraneous cognitive load reduction. Adapted versions of the papers, such as Braille, large-print, or Brazilian Sign Language (Libras) versions, were not considered for selection purposes. The selected questions met the following criteria: (i) they addressed affine functions; (ii) they could be restructured without altering their conceptual complexity; and (iii) they were appropriate for the participants' level of schooling.

Each instrument was organised into two versions (Sheet A and Sheet B), structured so that the questions alternated between their original and reduced-load versions. Half of the students initially completed Sheet A, while the other half completed Sheet B. Halfway through the allotted time, the sheets were exchanged between the groups so that all participants encountered both versions of the questions. This procedure was intended to minimise order effects and ensure the comparability of the responses.

Data collection was conducted in three complementary stages. In the first stage, the students solved the questions individually and were given approximately 50 minutes to record their answers, strategies, and interpretations. In the second stage, they were organised into small groups and discussed their solutions for approximately 35 minutes. At this stage, they were instructed not to alter their individual written work but to share and discuss the strategies they had adopted. In the third stage, a whole-class discussion lasting approximately 15 minutes was held, during which the groups presented their main observations, particularly regarding the differences and similarities between the original and reduced-load versions of the questions.

RESULTS AND ANALYSIS

The results were developed from an analysis of the students' written work and the notes taken on the interactions that occurred during the three stages of data collection — individual problem solving, small-group discussions, and the whole-class discussion. In accordance with the qualitative interpretative approach, the analysis focused on identifying evidence of the recruitment of Executive Functions — Working Memory, Inhibitory Control, and Cognitive Flexibility. Owing to space limitations, this article considers the cognitive conditions imposed by the original and reduced-load versions of Questions 1 and 2.

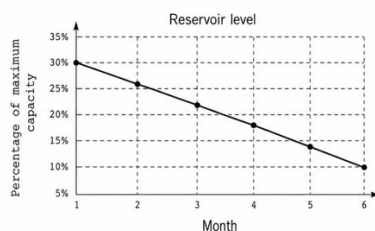
The episodes analysed in this article were selected based on their potential to reveal cognitive processes in action, particularly those related to the maintenance, organisation, and transformation of information during problem solving. The excerpts were organised to enable comparisons between the versions of each question and the students' written work, as illustrated in Figure 1 for Question 1 and Figure 2 for Question 2.

Figure 1

Question 1 in its original version (B) and reduced-load version (A)

The water level in a reservoir was monitored over a period, and the result is shown in the graph below. Suppose this linear trend continues over the next few months.

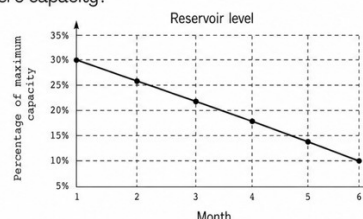
Under these conditions, what is the minimum time, after the sixth month, for the reservoir to reach zero capacity?



(A) reduced cognitive load

One of Brazil's major challenges is managing its natural resources, especially water resources. There is growing demand for water, and the risk of water shortages cannot be disregarded. The water level in a reservoir was monitored over a period, and the result is shown in the graph. Suppose this linear trend observed in the monitoring continues over the next few months.

Under these conditions, what is the minimum time, after the sixth month, for the reservoir to reach zero capacity?



(B) original cognitive load

Source: translated from Paula (2026).

Question 1 (Figure 1) involves interpreting a straight-line graph associated with an affine function. Students are required to identify the rate of change and extrapolate the line beyond the interval shown in order to determine the point in time at which the level reaches zero. The task recruits skills expected of upper secondary school students, particularly those related to reading graphical representations and identifying patterns of variation.

However, a comparative analysis of the two versions of the item statement shows that, although the conceptual structure of the task remains unchanged, there are relevant differences in the cognitive demands associated with reading and understanding it. The original version contains redundant textual information that verbally reiterates aspects already made explicit in the graph. This redundancy does not contribute directly to solving the problem but requires additional processing by the student, thereby increasing extraneous cognitive load.

The reduced-load version, developed using the Translation technique, reorganises the item statement through linguistic simplification, the elimination of redundancies, and the replacement of potentially ambiguous expressions — such as “be extended” with “continue”. These modifications alter neither the mathematical content of the task nor its response options; rather, they reconfigure the conditions under which the information is accessed, making the structure of the problem situation more explicit.

Figure 2 presents Question 2, which addresses the concept of an affine function through a comparison between two plans (A and B), each of which can be represented by a linear function. To solve the problem, students must identify the expressions associated with each plan, substitute values, and compare the resulting costs in order to determine the best option for a given quantity. Although no graphical representations are provided, the task recruits the analysis of linear variation and the relationship between coefficients and the values assumed by the variable, content with which students have already had contact in upper secondary school.

Figure 2

Question 2 in its original version (B) and reduced-load version (A)

- A delivery company offers two plans:
- Plan A: fixed fee of R\$ 500.00 per month + R\$ 4.00 per kilogram shipped.
 - Plan B: fixed fee of R\$ 200.00 per month + R\$ 6.00 per kilogram shipped.

A manufacturer needs to ship 650 kilograms of goods over 6 months. Which alternative correctly assesses the manufacturer's decision to choose Plan B?

(A) The decision was good because Plan B will cost R\$ 500.00 less in total than Plan A would cost.

A delivery company provides services to other companies that manufacture and sell products. Product manufacturers may choose one of two plans offered by the delivery company. Under Plan A, a fixed monthly fee of R\$ 500.00 is charged, plus R\$ 4.00 for each kilogram shipped (to any destination within the service area). Under Plan B, a fixed monthly fee of R\$ 200.00 is charged, but the rate for each kilogram shipped rises to R\$ 6.00. A certain manufacturer had decided to purchase Plan A for a period of 6 months. However, after realizing that it would need to ship only 650 kilograms of goods over the entire period, it decided to purchase Plan B.

Which alternative correctly assesses the manufacturer's final decision to purchase Plan B?

(A) The decision was good for the manufacturer because Plan B will cost R\$ 500.00 less in total than Plan A would cost.

(A) reduced cognitive load

(B) original cognitive load

Source: translated from Paula (2026).

From a structural perspective, the original version of the question presents a lengthy and dense description, with information distributed throughout the text. This may increase the demands placed on Working Memory by requiring students to retain multiple elements simultaneously for subsequent comparison. The reduced-load version was developed using the Translation technique, with the removal of passages considered redundant, including expressions appearing in both the item statement and the response options — such as the repetition of the expression “for the manufacturer”. In addition, parts of the item statement were reorganised into bullet points, providing a clearer and more segmented structure for the information.

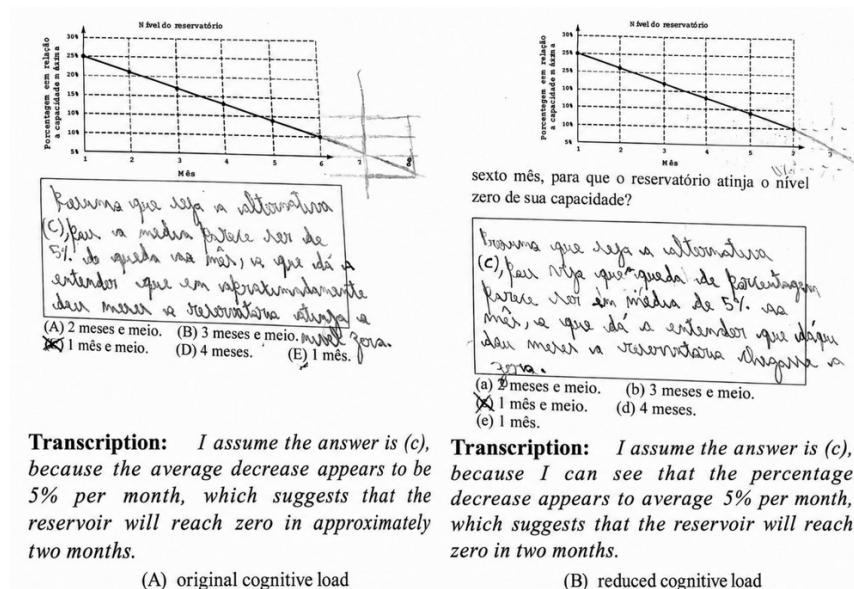
This reorganisation alters neither the mathematical content nor the nature of the task; rather, it changes how the task is presented, facilitating the identification and comparison of the information required to solve it. Even without the use of images, the arrangement of information into bullet points contributes to more efficient visual organisation. It may therefore be interpreted as a strategy for reducing extraneous cognitive load associated with the aesthetic dimension, insofar as it enhances logical clarity and facilitates navigation through the information.

WORKING MEMORY

The analysis of student E5's written work shows that solving the task depends on continuous co-ordination between reading the graph and drawing inferences about the behaviour of the function. As shown in Figure 3, in both versions, the student recruits a strategy based on extrapolating the linear trend, assuming an average rate of change of approximately 5% per month. This procedure entails actively maintaining information extracted from the graph and transforming it into a rule of variation that can be applied beyond the interval represented. It therefore involves Working Memory not merely as a temporary storage space, but as a system for manipulating and integrating information.

Figure 3

E5's solutions to both versions of Question 1: the original version (A) and the reduced-load version (B)



Source: Paula (2026).

A comparison of the two pieces of written work nevertheless reveals differences in how this process unfolds. In the original version, the student's explanation is more extensive and less linear, suggesting that greater effort is required to coordinate the information provided in the item statement and the graph. The presence of additional textual elements appears to impose a cognitive load that competes with the resources needed to develop the reasoning.

In the reduced-load version, by contrast, the explanation is more direct and closely aligned with the core of the problem, indicating a more efficient organisation of cognitive processing. This difference does not reflect a change in strategy, but rather a change in processing economy: the same cognitive resources are recruited, although in a more focused and less diffuse manner.

A particularly relevant aspect concerns the way the student implicitly simplifies the situation by assuming a constant average rate of change. This procedure reduces the complexity of the problem by limiting the number of elements that must be maintained simultaneously in Working Memory. Such simplification may be interpreted as a cognitive management strategy that enables the student to stabilise the reasoning process and sustain its progression.

INHIBITORY CONTROL

With regard to Inhibitory Control, the analysis of Question 1 indicates that its recruitment is associated with the need to regulate informational relevance in a context in which the item statement presents elements that are redundant in relation to the graphical representation. Unlike situations involving explicitly distracting information, the inhibitory demand in this case arises from the need to

select among semantically equivalent information presented in different formats (text and graph).

The nature of the task requires students to identify the linear trend from the graph and use it to perform an extrapolation. In the original version of the item statement, however, this same information is partially reiterated in the text, thereby introducing informational duplication. This duplication does not alter the mathematical content, but it increases the number of elements that must be considered and potentially inhibited during problem solving.

Although student E5 (Figure 3) does not employ explicit strategies for marking or filtering the item statement, the solution indicates an implicit selection of relevant information, with the graph prioritised as the main source of data for constructing the reasoning. In this sense, the absence of any reference to the redundant textual information suggests that these elements were not incorporated into the solution process, which may be interpreted as evidence of the regulation of informational relevance. Rather than an additional filtering effort, what can be observed is a direct orientation towards the central elements of the task, particularly in the reduced-load version, in which this prioritisation appears to occur more immediately.

This behaviour may be interpreted as evidence of the implicit selection of relevant information, insofar as the student bases the solution on the graphical representation without explicitly recruiting the additional textual elements. Such selection is not manifested through observable filtering strategies — such as underlining or other markings — but through the structure of the response itself, which remains focused on the relationship between variation and extrapolation.

The comparison between the two versions makes it possible to qualify this process. In the original version, the presence of redundant information broadens the set of potentially relevant elements, requiring the student to establish an implicit focus for the solution. In the reduced-load version, the removal of these redundancies makes the structure of the task more explicit, facilitating a more direct orientation towards the central information. In this sense, the difference between the versions does not necessarily indicate greater or lesser inhibitory capacity on the part of the student, but rather a change in the conditions under which the regulation of informational relevance occurs.

Another relevant aspect concerns the absence of interference in the solution process. Even in the original version, no interpretative deviations or inappropriate use of information can be observed, suggesting that the student is able to remain focused on the elements pertinent to the task. This finding is particularly important because it indicates that the presence of redundant information does not compromise this student's reasoning, although it may alter the processing conditions.

An analysis of the data from Question 2 makes it possible to extend the preceding interpretations regarding Inhibitory Control. Whereas in Question 1 the regulation of informational relevance is manifested implicitly — through the prioritisation of the graph over redundant textual elements — in Question 2 this same process becomes more visible, particularly in the strategies adopted by the students to manage the informational density of the item statement, as shown in Figure 4.

Figure 4

E9's solutions to both versions of Question 2: the original version (A) and the reduced-load version (B)

Uma empresa de entregas presta serviços para outras empresas que fabricam e vendem produtos. Os fabricantes dos produtos podem contratar um entre dois planos oferecidos pela empresa que faz as entregas. No plano A, cobra-se uma taxa fixa mensal no valor de R\$ 500,00, além de uma tarifa de R\$ 4,00 por cada quilograma enviado (para qualquer destino dentro da área de cobertura). No plano B, cobra-se uma taxa fixa mensal no valor de R\$ 200,00, porém a tarifa por cada quilograma enviado sobe para R\$ 6,00. Certo fabricante havia decidido contratar o plano A por um período de 6 meses. Contudo, ao perceber que ele precisará enviar apenas 650 quilogramas de mercadoria durante todo o período, ele resolveu contratar o plano B.

Qual alternativa avalia corretamente a decisão final do fabricante de contratar o plano B?

500	200
x 650	x 650
32500	13000
+ 3000	+ 3900
35500	16900

porque o preço por
mês saiu mais barato.

500	200
x 650	x 650
32500	13000
+ 3000	+ 3900
35500	16900

porque o preço por
mês saiu mais barato.

- Plano A: taxa fixa de R\$ 500,00 por mês + R\$ 4,00 por quilograma enviado. 504,00
- Plano B: taxa fixa de R\$ 200,00 por mês + R\$ 6,00 por quilograma enviado. 206,00

Um fabricante precisa enviar 650 quilogramas de mercadoria em 6 meses. Qual das alternativas avalia corretamente a decisão de o fabricante escolher o plano B?

504	206
x 6	x 6
3024	1236

Transcription: Because the monthly price was lower.

(A) original cognitive load

(B) reduced cognitive load

Source: Paula (2026).

In the case of student E9 (Figure 4), the use of markings in the text — such as highlighting and circling — indicates an explicit attempt to select relevant information from a lengthier item statement. Unlike Question 1, in which informational redundancy is presented more subtly, Question 2 requires students to engage more actively in the filtering process, making the recruitment of Inhibitory Control more evident. In the reduced-load version of the same question, the decrease in these markings suggests that the reorganisation of the item statement reduces the need for active selection, as the structure of the information guides the student's attention more directly.

This comparison provides a more nuanced interpretation of Question 1. Although no explicit filtering strategies can be observed in that case, the data suggest that the selection of relevant information is also present, albeit in a less visible form. Thus, the absence of markings or interventions in the text does not indicate an absence of Inhibitory Control, but rather a condition in which the demand for filtering is lower or addressed more implicitly.

COGNITIVE FLEXIBILITY

With regard to Cognitive Flexibility, the analysis of Question 1 indicates that its recruitment occurs less explicitly than that of Working Memory and Inhibitory Control. It is manifested primarily in the ability to project and adapt reasoning based on an identified regularity, as well as to sustain the course of action when faced with a situation that requires going beyond what is directly represented.

The nature of the task — interpreting a straight-line graph and extrapolating the line to determine the point in time at which the level reaches zero — requires students not only to read the available information but also to reorganise it within a new context, beyond the interval shown. In this sense, Cognitive Flexibility is not expressed through alternation among multiple strategies, but through the ability to extend an identified pattern to a situation that is not explicitly presented.

This process can be observed in student E5's written work, presented in Figure 3. In both versions, the student identifies the linear trend and mentally projects the behaviour of the line, assuming an average decrease of approximately 5% per month. This projection entails a reorganisation of the information: the graph, initially restricted to a specific time interval, comes to be interpreted as representing continuous behaviour that can be extended beyond the data shown.

A first indication of Cognitive Flexibility therefore lies in the transition from reading to projection. The student does not merely describe the graph, but transforms the visual information into a rule of variation, which is then applied within a new context. This operation requires the ability to reinterpret the initial representation and adapt it to the demands of the task.

A second indication can be observed in how the student stabilises this rule of variation. By assuming a constant average rate, E5 simplifies the situation, reducing the need to consider possible local variations in the graph. This simplification is not made explicit in the item statement but emerges as a way of cognitively reorganising the problem. Such a procedure may be interpreted as a strategic adaptation that enables the student to work with a more manageable model of the situation, thereby supporting the continuation of the reasoning process.

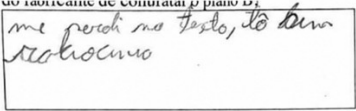
A third aspect can be identified in the absence of a shift in strategy, which, in this case, does not indicate cognitive rigidity but rather the suitability of the initial strategy to the demands of the task. The maintenance of the extrapolation procedure suggests that the student quickly recognises the nature of the problem and does not need to test alternative approaches. In this sense, Cognitive Flexibility is manifested as the ability to sustain an effective strategy without the need for successive reconfigurations.

Although Cognitive Flexibility in Question 1 is manifested predominantly through the projection and stabilisation of a strategy — as observed in the case of student E5, who extrapolates the linear trend of the graph without needing to change procedures — its articulation with data from Question 2 makes it possible to broaden the understanding of this process by revealing how it is manifested in contexts involving a disruption and subsequent resumption of reasoning.

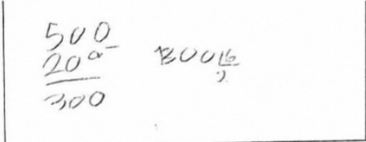
In the case of student E8 (Figure 5), the original version of Question 2 is marked by an explicit interruption of the solution process, expressed in the statement, "I got lost in the text; I can't think straight". Under this condition, what can be observed is not merely difficulty in maintaining information, but a temporary inability to continue the cognitive activity. In the reduced-load version of the same question, however, the student begins to record calculations and solution attempts, indicating that the process has resumed and that the student has re-engaged with the activity.

Figure 5

E8's solutions to both versions of Question 2: the original version (A) and the reduced-load version (B)



Transcription: *I got lost in the text; I can't think straight.*



(A) original cognitive load

(B) reduced cognitive load

Source: Paula (2026).

This movement — from interruption to resumption — constitutes a relevant indication of Cognitive Flexibility, not in the sense of alternating between different strategies, but as the ability to reorganise cognitive activity following an initial blockage. Unlike Question 1, in which E5's strategy remains stable from the outset, Question 2 reveals situations in which the student must reconstruct the starting point of the solution process.

The comparison between the two questions therefore makes it possible to distinguish two complementary manifestations of Cognitive Flexibility: in Question 1, it is expressed through the projection and continuation of reasoning based on an identified regularity; in Question 2, it is expressed through the resumption and reorganisation of the activity following an interruption. In both cases, reducing extraneous cognitive load changes the conditions under which this flexibility is exercised.

DISCUSSION

The results of this study provide a deeper understanding of the relationship between the structure of mathematical tasks and the recruitment of Executive Functions. They show that students' performance cannot be interpreted solely in terms of conceptual knowledge but must also be analysed in light of the cognitive conditions imposed by the organisation of the item statements.

Working Memory, Inhibitory Control, and Cognitive Flexibility are known to operate in an integrated manner during problem solving (Miyake et al., 2000; Diamond, 2013). The data analysed indicate that this integration is not static but sensitive to the structural characteristics of the task. In particular, the comparison between the original and reduced-load versions of the questions shows that reorganising the item statement changes the conditions under which these processes are recruited.

From the perspective of Cognitive Load Theory (Sweller, 1988; 2003), these results may be interpreted as an effect of reducing extraneous cognitive load. The modifications introduced — such as linguistic simplification, the elimination of redundancies, and visual reorganisation — do not alter the conceptual complexity of the tasks (intrinsic load), but reduce unnecessary demands associated with information processing. In this sense, the data support a central principle of the theory: the way in which information is presented directly influences the use of Working Memory resources.

This interpretation is consistent with the findings of Chagas (2019), who showed that structural changes to ENEM items can affect students' performance. The present study, however, represents an analytical advance by revealing not only differences in performance but also differences in the cognitive processes recruited during problem solving. Thus, whereas Chagas (2019) identifies quantitative effects of reducing extraneous load, the results presented here contribute by elucidating the cognitive mechanisms underlying these effects.

With specific regard to Executive Functions, the data indicate that reducing extraneous cognitive load appears to reorganise the distribution of cognitive demands. Working Memory, for example, is no longer required to such a great extent to retain and co-ordinate dispersed information and can instead be directed towards manipulating the relevant mathematical relationships. Similarly, Inhibitory Control operates in a context involving less informational competition, reducing the need for active filtering. Cognitive Flexibility, although it does not necessarily require a change in strategy, is manifested under conditions that are more conducive to the continuation or resumption of reasoning.

This interpretation is directly related to the results presented by Dalto (in press), which show that undergraduate mathematics teacher education students with less developed executive functioning are more sensitive to variations in extraneous cognitive load. Although the present study does not focus on the direct measurement of Executive Functions, the qualitative data indicate that reorganising the item statement may serve as a cognitive compensatory mechanism by reducing dependence on more demanding executive processes and facilitating task completion.

Another relevant aspect concerns the role of visuospatial representations. In Question 1, interpreting and extrapolating the graph requires the co-ordination of visual information and inferences about variation, recruiting the visuospatial component of Working Memory. In this respect, the results are consistent with studies indicating the importance of visuospatial abilities for mathematical performance, particularly in tasks involving graphical representations and the manipulation of mental images (Lowrie, Logan & Ramful, 2017; Mix, 2019).

This relationship is explored further in the study by Dalto and Paula (2026), which shows that solving ENEM questions frequently involves visualisation strategies, although these are not sufficient in themselves to ensure successful task completion. The results presented here reinforce this perspective by indicating that, even in tasks with a strong visuospatial component, performance depends on the interaction between different cognitive processes, including Executive Functions and prior mathematical knowledge.

Furthermore, reorganising the item statement may facilitate the recruitment of visuospatial strategies by reducing textual interference. By making the structure of the task more explicit, the reduced-load version enables students to direct their attention towards the graphical representation, facilitating the identification of patterns of variation and the construction of inferences. This result suggests that reducing extraneous cognitive load may enhance not only executive processing but also the use of visuospatial representations in problem solving.

More broadly, the results suggest that performance on mathematical tasks emerges from the interaction between two sets of factors: (i) individual characteristics, particularly those related to Executive Functions; and (ii) the structural characteristics of the task, associated with extraneous cognitive load. This integrated perspective, previously proposed by Dalto (in press), is reinforced by the qualitative data presented here, which show how small changes in the organisation of an item statement can produce significant changes in the conditions under which problem solving occurs.

The results also have implications for Mathematics Education, as they show that task structure is relevant to understanding problem-solving processes. More than a matter of presentation, the organisation of information may influence the cognitive conditions under which students interpret, select, and co-ordinate the information required to solve a problem. From this perspective, the design of tasks and assessment instruments may benefit from strategies that reduce unnecessary cognitive demands without altering the conceptual complexity of the content involved. In addition, the findings reinforce the importance of recognising that some of students' difficulties and errors may be associated not only with mathematical knowledge but also with the structural characteristics of the tasks. The integration of Executive Functions, Cognitive Load Theory, and Mathematics Education therefore broadens the possibilities for understanding the processes involved in mathematical learning and problem solving.

FINAL CONSIDERATIONS

This study sought to understand how the structural organisation of mathematical tasks affects the cognitive conditions under which they are solved, with an emphasis on the relationship between extraneous cognitive load and the recruitment of Executive Functions in a school setting. By prioritising a qualitative analysis of problem-solving processes, the investigation provided access to dimensions of performance that extend beyond whether an answer is correct or incorrect and are manifested in how students interact with the tasks.

One of the main contributions of this study lies in demonstrating that the influence of item-statement structure is not limited to facilitating or hindering the initial understanding of the task, but also shapes the cognitive pathway through which it is solved. The study therefore advances the field by proposing an interpretation of mathematical performance as the outcome of a dynamic relationship between the organisation of information and executive functioning, showing that the way in which information is made available to students actively contributes to shaping their problem-solving processes.

In relation to previous research, this study broadens the scope of investigations into cognitive load by shifting the focus from performance-centred analyses to a process-oriented approach. Whereas previous studies have demonstrated the effects of reducing extraneous load in terms of correct responses, the results presented here contribute by indicating how these effects materialise in classroom cognitive activity, thereby offering elements for understanding the mechanisms involved in this relationship. Similarly, by integrating Cognitive Load Theory with the field of Executive Functions, the study contributes to a theoretical relationship that has received little empirical investigation in Mathematics Education.

From an educational perspective, the results reinforce the proposition that task structure influences the cognitive conditions under which mathematical activity is performed. In this sense, the findings suggest that decisions concerning the organisation and presentation of information may help reduce unnecessary cognitive demands, thereby supporting students' engagement in mathematically demanding tasks. These results provide a basis for designing tasks and assessment instruments that are more sensitive to the cognitive conditions involved in mathematical learning.

Nevertheless, the results should be interpreted in light of several limitations. The analysis focused on a specific set of tasks and a small number of participants, which restricts the generalisability of the findings. Furthermore, the absence of direct measures of Executive Functions limits the possibility of establishing more precise relationships between performance and cognitive functioning, as the inferences made are based on indirect evidence drawn from the students' written work. The variability of these written records also constitutes a limitation, as, in some cases, they did not provide detailed access to the problem-solving processes. Another limitation concerns the absence of verbal protocols, interviews, or think-aloud strategies, which could have provided more direct evidence of the cognitive processes recruited by students while solving the tasks and enabled a deeper understanding of the mechanisms involved in maintaining, selecting, and reorganising information throughout the activity.

Future research may therefore advance this agenda by integrating different methodologies and combining qualitative analysis with standardised instruments for cognitive assessment. Studies involving a larger and more diverse range of tasks and participant profiles may contribute to validating and refining the findings presented here. In addition, investigations into pedagogical interventions based on the structural reorganisation of tasks could provide further evidence regarding the effects of these strategies on the teaching and learning of Mathematics.

This study contributes to the field of Mathematics Education by showing that understanding mathematical performance requires consideration not only of what students know, but also of the cognitive conditions under which that knowledge is recruited. By highlighting the role of task structure in this process, the study reinforces the importance of an approach that integrates cognitive and didactic dimensions, thereby broadening the possibilities for research and intervention in Mathematics Education.

NOTE

1. The article was translated into English by the authors with the assistance of ChatGPT (version 5.6 Sol) and proofread by Isabela de Barros Vilas Boas. Email: isabelabvb@outlook.com

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