COGNITIVE LOAD CONTROL IS A CONTROL MECHANISM WORKING MEMORY, STIMULATING THE FLEXIBLE INTELLIGENCE OF UNIVERSITY STUDENTS

O CONTROLE DA CARGA COGNITIVA GERENCIA A MEMÓRIA DE TRABALHO, ESTIMULANDO A INTELIGÊNCIA FLEXÍVEL DOS ESTUDANTES

EL CONTROL DE LA CARGA COGNITIVA ES UN MECANISMO DE CONTROL DE LA MEMORIA DE TRABAJO, ESTIMULANDO LA INTELIGENCIA FLEXIBLE DE LOS ESTUDIANTES UNIVERSITARIOS

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ABSTRACT: In the context of digitalization in higher education, students are required to process increasingly complex information in limited time, which intensifies the risk of cognitive overload. This conceptual-analytical study examines cognitive load control as a pedagogical mechanism for regulating working memory and supporting cognitive flexibility among university students. The study is based on Cognitive Load Theory and a synthesis of recent literature on digital didactics, instructional design, motivation, and professional training. The methodological approach is literature-based; no direct experiment or survey sample was used. The analysis distinguishes literature-derived theoretical assumptions from the article's own synthesis of pedagogical implications. The results show that effective cognitive load control depends on three complementary actions: adapting task complexity to students' prior knowledge, reducing extraneous information, and activating meaningful schema construction through multimodal and professionally oriented tasks. The article contributes by systematizing practical instructional strategies and by clarifying how cognitive load management can support academic performance and professional learning in digital environments.

KEYWORDS: Cognitive load theory. Working memory. Cognitive flexibility. Digital higher education. Instructional design.

RESUMO*: No contexto da digitalização do ensino superior, os estudantes precisam processar informações cada vez mais complexas em tempo limitado, o que intensifica o risco de sobrecarga cognitiva. Este estudo conceitual-analítico examina o controle da carga cognitiva como mecanismo pedagógico para regular a memória de trabalho e apoiar a flexibilidade cognitiva de estudantes universitários. A pesquisa baseia-se na Teoria da Carga Cognitiva e em uma síntese da literatura recente sobre didática digital, design instrucional, motivação e formação profissional. A abordagem metodológica é bibliográfica; não foi realizado experimento direto nem aplicada amostra por questionário. A análise diferencia pressupostos teóricos derivados da literatura e a síntese própria das implicações pedagógicas. Os resultados indicam que o controle eficaz da carga cognitiva depende de três ações complementares: ajustar a complexidade das tarefas ao conhecimento prévio, reduzir informações irrelevantes e ativar a construção significativa de esquemas por meio de tarefas multimodais e profissionalmente orientadas.*

PALAVRAS-CHAVE*: Teoria da carga cognitiva. Memória de trabalho. Flexibilidade cognitiva. Ensino superior digital. Design instrucional.*

RESUMEN*: En el contexto de la digitalización de la educación superior, los estudiantes deben procesar información cada vez más compleja en un tiempo limitado, lo que intensifica el riesgo de sobrecarga cognitiva. Este estudio conceptual-analítico examina el control de la carga cognitiva como mecanismo pedagógico para regular la memoria de trabajo y apoyar la flexibilidad cognitiva de los estudiantes universitarios. La investigación se basa en la Teoría de la Carga Cognitiva y en una síntesis de literatura reciente sobre didáctica digital, diseño instruccional, motivación y formación profesional. El enfoque metodológico es bibliográfico; no se realizó un experimento directo ni se aplicó una muestra mediante encuesta. El análisis distingue los supuestos teóricos derivados de la literatura de la síntesis propia de implicaciones pedagógicas. Los resultados muestran que el control eficaz de la carga cognitiva depende de tres acciones complementarias: adaptar la complejidad de las tareas al conocimiento previo, reducir la información irrelevante y activar la construcción significativa de esquemas mediante tareas multimodales y orientadas profesionalmente.*

PALABRAS CLAVE*: Teoría de la carga cognitiva. Memoria de trabajo. Flexibilidad cognitiva. Educación superior digital. Diseño instruccional.*

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INTRODUCTION

Digitalization has changed the conditions of university teaching by increasing the volume, speed, and complexity of information that students must process (Ukolova et al., 2024; Ukolova & Afanasyev, 2023). In this context, cognitive load control becomes a pedagogical problem rather than only a technical issue. When instructional materials contain excessive or poorly organized information, students' working memory is overloaded, which can reduce comprehension, information retention, and the ability to solve professional problems (Bozhkova et al., 2025; Mukhametkairov et al., 2024; Tutkova et al., 2024). This enables thorough planning of practical steps and orientation toward existing successful research results on students' memory capacity, memory overload limits, and navigation through cognitive loads, while also engaging digital technology experts (Aziyev et al., 2024; Kabzhanova et al., 2024; Zhukova et al., 2025).

Although recent studies discuss digital technologies, professional competence, and instructional innovation in higher education, cognitive load management is often presented as a broad theoretical principle rather than as a clearly described mechanism for regulating working memory in university students (Goncharenko & Semenkova, 2023; Ling et al., 2023; Polozhentseva et al., 2024). It is important that existing knowledge in this area, examples of best practices, and evidence of effectiveness are available in a simple, readable, and concise format (Belousova et al., 2023; Muskhanova & Avtaeva, 2023; Starostenkov, 2023).

This creates a research gap: the relationship between Cognitive Load Theory, digital learning conditions, and concrete pedagogical strategies for professional training remains insufficiently systematized.

The central problem addressed in this article is how cognitive load control can be organized so that it does not merely reduce the amount of information offered to students, but helps them transform information into stable long-term memory schemas and flexible professional reasoning.

The purpose of the article is to justify pedagogical approaches to managing cognitive load among university students in order to improve the effectiveness of professional education in the context of digitalization.

To make the argument clearer, the article distinguishes three levels of analysis: the theoretical assumptions derived from Cognitive Load Theory, the methodological procedure used to organize the literature, and the article's own synthesis of pedagogical implications for university instructors.

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METHODS AND METHODOLOGY

This study follows a conceptual-analytical and literature-based design. Its purpose is not to measure cognitive load in an experimental sample, but to systematize pedagogical approaches that can be used to regulate it in higher education. The research context is university teaching under conditions of digitalization and increasing information density. The source corpus includes recent publications and methodological materials cited in the reference list, with priority given to works on Cognitive Load Theory, digital didactics, professional competence formation, instructional design, motivation, and student learning.

The analytical procedure consisted of four steps: (1) identifying recurring concepts in the literature, including working memory, long-term schemas, extraneous load, prior knowledge, motivation, and multimodal presentation; (2) grouping these concepts into the categories of intrinsic, extraneous, and germane cognitive load; (3) comparing the pedagogical strategies proposed in the literature with the needs of university students in professional training; and (4) formulating practical implications for instructors. Since no direct student survey, experiment, or intervention was conducted, the study does not report a respondent sample or statistical instruments. Instead, the main analytical instrument is a thematic synthesis matrix based on the categories of Cognitive Load Theory.

RESULTS

Cognitive load is a concept that explains the mechanisms capable of regulating students' working memory, either hindering learning and academic performance or stimulating cognitive flexibility. According to Cognitive Load Theory, tasks that exceed the natural limits of memory and attention lead to significant reductions in information retention and learning success.

The modern Australian educational psychologist John Sweller is known for constructing a theory based on the assumption that cognitive structures—specifically schemas and combinations of elements—form the foundation of an individual's knowledge. He developed this theory after reading George Miller's work on information processing, which showed that short-term memory is limited in the number of elements it can handle simultaneously. One of the core principles of Sweller's cognitive load theory is that a high cognitive load can negatively affect task performance. Moreover, it highlights the importance of recognizing that the experience of cognitive load is not the same for everyone. For instance, older adults, university

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students, and children may experience different degrees of cognitive load under the same conditions (Rodríguez, 2023).

Cognitive psychology defines cognitive load as the mental effort required of both working and long-term memory. Sweller proposed guidelines for presenting information in ways that identify and encourage actions that optimize intellectual performance.

According to Sweller, the content of long-term memory consists of "complex structures that allow us to perceive, reflect, and solve problems, rather than a collection of memorized facts. These structures, called schemas, enable us to treat multiple elements as a single unit" (Rodríguez, 2023). Schemas are the cognitive structures that form the foundation of knowledge. They are acquired through learning and experience over the course of life and can contain other schemas within them. Learning involves modifying the schematic structures of long-term memory and manifests in improved memorization efficiency. This efficiency increases as students become more familiar with the material because their schemas evolve in a way that enables working memory to process information more effectively and transfer it to long-term memory—the basis of cognitive flexibility. To "reset" the schemas, memory load must be reduced.

The methods for solving different tasks can be changed by presenting them without specifying goals or providing pre-solved examples. The aim should be to avoid tools and techniques that place excessive demands on memory. By reducing the load on working memory caused by the need to integrate multiple sources of information, it becomes possible to engage students' flexible intelligence by offering separate information sources and attempting to expand working memory capacity through the use of auditory and visual channels. This is particularly effective when available information sources are necessary for overall comprehension and not redundant.

Cognitive load management is, in essence, an instructional design theory that seeks to explain and apply our cognitive architecture—that is, how we process information. During the learning process, information is held in working memory until it has been processed enough to be stored in long-term memory. The capacity of working memory is limited, and when too much information is introduced at once, overload occurs, causing much of the information to be lost and not retained.

According to Cognitive Load Theory, learning becomes more effective when instructional methods include the following:

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- Measuring prior experience and adapting instruction accordingly;
- Reducing the problem space by breaking problems down into components and using independent sub-tasks;
- Integrating multiple sources of information when feasible;
- Increasing working memory efficiency by using both visual and auditory channels.

> Die kognitive Belastung ist ein Konzept, das erklärt, wie die Anforderungen an das Arbeitsgedächtnis einer Person das Lernen und die Leistung hemmen können. Nach der Theorie der kognitiven Belastung führen Aufgaben, die die inhärenten Grenzen des Gedächtnisses und der Aufmerksamkeit überschreiten, zu einer überstürzten Abnahme des Behaltens von Informationen und des Erfolgs. Kognitive Belastung in der Fertigung: Wie Augmentation die Entscheidungsfindung verbessern kann. (Klaess, 2019)

> Cognitive load is a concept that explains how demands on a person's working memory can hinder learning and performance. According to cognitive load theory, tasks that exceed the inherent limitations of memory and attention result in a sharp decline in information retention and success. (Azarenko, 2024)

Cognitive load increases when completing complex and novel tasks, especially when irrelevant inclusion/exclusion criteria and topics are present. The less extraneous load there is, and the greater the learner's prior knowledge and clarity of inclusion criteria, the more effective and accurate the inclusion or exclusion of curricular sections becomes, along with the relevance of the concept and the reliability of cognitive resources. These may include educational scenarios that are meaningful and contribute to the learning process in an institutional context tied to a specific academic specialty, as well as thematic coverage that ensures broad exposure and effectiveness of the topic.

It is important to note that inclusion and exclusion criteria are observable variables, meaning they are accessible to direct observation. Once selected, it becomes evident that they are all linked to an imperfect definition of the educational context. On one hand, this may be due to insufficient attention or focus. On the other, there is a blurred line between education and training within the professional approach. This could be interpreted as a sign that cognitive load does not differ significantly. However, we believe that further clarification is required in this field depending on the ambiguity of the criteria and the relevance of the results (Goryushko & Samochadin, 2018).

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> Long-term memory has no volume limit. Moreover, when familiar information is transferred into working memory, its capacity or duration constraints no longer apply. In other words, any amount of information can be memorized if done correctly. The transfer of knowledge from short-term to long-term memory for storage is the very process of learning. And cognitive load theory explains how to do this more effectively. (p. 35)

The analysis of the relationship between increased cognitive load and teacher professionalism primarily highlights the need for continuous professional development, driven by the rapid advancement in various fields such as business, healthcare, education, and training, as well as the preparation of graduates for successful engagement in all spheres of life. The alignment between education and employment is oriented toward the economy, culture, and professionalism of the university educational process. In this sense, the higher education system not only responds to emerging needs but also generates them, and at the same time serves as a foundation for success across multiple domains.

One of the key factors influencing learning effectiveness in cognitive psychology and pedagogy is the organization and management of cognitive load. As noted in the literature (Chicherina & Wang, 2023),

> instructional strategies that do not consider students' cognitive load may hinder perception, processing, retention, and application of information during the learning process and lower the quality of learning outcomes. Within the context of educational activity, instruction based on cognitive load theory becomes particularly relevant. Academic literature provides corresponding recommendations for both instructors and students. This article presents a conceptualization of cognitive load within educational activity and systematizes recommendations for managing students' cognitive load in three areas: managing intrinsic cognitive load, reducing extraneous cognitive load, and activating germane cognitive load. These include specific methods and techniques for managing cognitive load during instruction. (p. 8)

Throughout the learning process, new professional standards become institutionalized as mandatory. Since universities are both research and academic institutions, this requirement is embedded within their structure. Science also relies on a complex system of assessment and

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testing that constantly validates the success of its academic initiatives. A return to using only traditional teaching methods, without digital-based technologies, is no longer feasible.

This does not mean that professional knowledge based on traditional experience loses its value, nor that scientifically grounded technologies must prove their superiority in training. In this context, growing attention is being paid to the quality of higher education, which must prepare students for work in various domains, foster their understanding of cultural diversity in the era of globalization, and develop the ability to make judgments within both national ethical-moral frameworks and the context of navigating high cognitive load.

Cognitive load—or overload—is a crucial consideration, given that every individual's cognitive capacity is naturally constrained by the limits of working memory. If a student is exposed to too much information, and if tasks impose excessively high cognitive demands or the content is too complex, then it becomes reasonable for the instructor to adopt simpler methods, grounded in empirical feedback from students.

Using cognitive tests, the influence of students' cognitive abilities on their ability to assimilate corresponding cognitive information can be studied, along with the significant synergy between core sections of an integrated curriculum. This, in our view, allows for better regulation of cognitive load—through adjustment, structuring, refinement, and deeper immersion into the professional field—which, as demonstrated by our teaching experience, can be seen as a positive effect. Students benefit not only from professional knowledge but also from a sufficiently high level of general informational awareness.

It should be noted that such high effectiveness is demonstrated primarily by highly motivated and successful students, and one should be cautious not to impose excessive stigmatization or unrealistic expectations. Nevertheless, the demonstration of subsequent comparable professional achievements is encouraging.

Research into cognitive load has shown that learning focused on solving professional problems requires students to seek solutions without placing an excessive extraneous cognitive load on themselves, as the resources of working memory should be directed solely toward actions relevant to solving the task at hand. At the same time, extraneous cognitive load does not always hinder learning—it can actually enhance it. It may even support a scientific approach to work, since solving certain problems and working in tandem toward those goals sets a high bar for the use of effective instructional design. This design helps unleash the potential for increasing the necessary overall cognitive load, which positively influences students' working memory. It also engages them with multiple sources or materials simultaneously, requiring

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attention to be divided between visual and auditory information essential for comprehension. These multiple sources must then be mentally integrated, allowing faster and less effortful integration with prior experience.

It is important for instructors to understand the current level of student learning and the extent to which they require additional support and auxiliary mechanisms—for example, interactivity or clarification of meaningful links between new content and what students already know.

The presence of certain cognitive abilities enables students to grasp material more easily and complete tasks without major effort, allowing them to concentrate on developing skills related to speed and precision in managing cognitive load. These abilities also include the capacity to recognize the professional, general educational, and ethical significance of academic topics; to understand, acknowledge, and make well-reasoned judgments about national and other values. This follows a chain: professional approach → knowledge and understanding of values and norms → generation and reflection of factual information → reflection and evaluation → awareness of one's attitude and the moral significance of decisions → decision-making.

We believe it is essential to emphasize not only professional, high-quality intellectual training, but also the cultivation of students' critical thinking regarding their own and other cultures, backgrounds, personal value systems, and sensitivity to moral and ethical situations. A personal, almost imprinting-like process plays a decisive role in shaping the moral perception of the relevance of educational content in general. This perception depends on upbringing, cultural or religious affiliation, and foundational ethical knowledge, which emerge within the stream of cognitive load and determine the quality of professional education.

FINAL CONSIDERATIONS

The article demonstrates that cognitive load control can be understood as a pedagogical mechanism for regulating working memory and supporting cognitive flexibility in university students. Its main contribution is the systematization of scattered theoretical and methodological positions into a coherent framework that links prior knowledge, working-memory limitations, schema formation, and professional learning in digital higher education.

The study clarifies that effective instruction should not aim to simplify all learning tasks. Instead, instructors should reduce unnecessary extraneous load while preserving meaningful

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cognitive effort that supports analysis, reflection, and the construction of long-term memory schemas. This distinction is important because professional education requires not only easier access to information, but also the ability to process, evaluate, and apply it flexibly.

For pedagogical practice, the findings suggest several recommendations: assess students' prior knowledge before introducing complex tasks; use worked examples and staged problem-solving; avoid redundant digital materials; combine visual and auditory information only when it improves comprehension; and include reflection or consultation activities that help students become aware of their own information-processing strategies.

The added value of the investigation lies in showing that cognitive load control is not an isolated psychological concept but a practical component of instructional design in digital higher education. When used deliberately, it can help instructors organize learning environments that protect working memory, strengthen long-term knowledge structures, and support students' flexible intellectual development.

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