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Relationship between working memory capacity and academic performance in Ecuadorian adolescents

Relación entre capacidad de memoria operativa y desempeño académico en adolescentes ecuatorianos

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Ronny Eduardo Sánchez López
https://orcid.org/0009-0004-8754-6811
rsanchezlop@ucvvirtual.edu.pe
Universidad César Vallejo. Peru

Abstract

This research analyzed the relationship between working memory and academic performance in adolescents aged fifteen to eighteen from a school in the province of Guayas, Ecuador. The main objective was to examine how the ability to retain and manipulate information in working memory relates to academic performance in various subject areas. To this end, a quantitative correlational approach was used, applying standardized tests that assessed both variables in a representative sample of students. The results revealed a significant positive relationship, demonstrating that students with greater working memory capacity showed better academic performance in key subjects. This association underscores the importance of executive cognitive functions for academic success in adolescence. Furthermore, the study introduces innovative aspects by using instruments adapted to the Ecuadorian context, allowing for more precise and culturally relevant data. This methodological contribution facilitates a greater understanding of the role that cognitive processes play in the local educational setting and can guide future research and educational policies. Taken together, these findings provide relevant empirical evidence for analyzing cognitive factors that influence adolescent learning in Ecuador, strengthening the scientific basis on the relationship between working memory and school performance.

Keywords: adolescents, working memory, cognitive processes, academic performance.

Resumen

La presente investigación analizó la relación entre la memoria operativa y el rendimiento académico en adolescentes de quince a dieciocho años pertenecientes a una unidad educativa de la provincia del Guayas, Ecuador. El objetivo principal fue examinar cómo la capacidad para retener y manipular información en la memoria operativa se relaciona con el desempeño académico en diversas áreas del conocimiento. Para tal fin, se empleó un enfoque cuantitativo de tipo correlacional, aplicando pruebas estandarizadas que evaluaron ambas variables en una muestra representativa de estudiantes. Los resultados revelaron una relación positiva significativa, evidenciando que los estudiantes con mayor capacidad en memoria operativa mostraron un mejor rendimiento académico en asignaturas clave. Esta asociación subraya la importancia de las funciones cognitivas ejecutivas para el éxito escolar en la adolescencia. Además, el estudio introduce aspectos innovadores al usar instrumentos adaptados al contexto ecuatoriano, lo que permite obtener datos más precisos y culturalmente pertinentes. Esta contribución metodológica facilita un mayor entendimiento del papel que desempeñan los procesos cognitivos en el ámbito educativo local y puede orientar futuras investigaciones y políticas educativas. En conjunto, estos hallazgos aportan evidencia empírica relevante para analizar factores cognitivos que influyen en el aprendizaje adolescente en Ecuador, fortaleciendo la base científica sobre la relación entre memoria operativa y desempeño escolar.

Palabras clave: adolescentes, memoria operativa, procesos cognitivos, rendimiento académico.

Introduction

In recent years, the analysis of mental processes involved in school learning has gained increasing importance within the fields of educational psychology and learning sciences. Understanding these cognitive processes is fundamental for comprehending how students acquire, process, and apply knowledge across various academic domains. Among these processes, working memory is recognized as an essential cognitive ability for

understanding individual differences in academic performance, particularly during adolescence, a stage marked by significant neural, psychological, and social changes (Packiam et al., 2011).

Working memory is defined as the mechanism that enables the temporary storage and manipulation of information necessary for executing complex mental tasks, such as text comprehension, problem-solving, and mathematical reasoning (Baddeley, 2003). This cognitive function acts as a kind of “mental whiteboard” that holds active information while further intellectual operations are performed. Recent studies have demonstrated that working memory capacity is a relevant predictor of academic performance in fundamental areas such as mathematics, science, and reading comprehension, both in international contexts and throughout Latin America (Holmes & Gathercole, 2014).

In this regard, research such as that conducted by Sánchez (2021) in Ecuador shows that adolescents with limitations in their working memory face greater challenges in learning, which directly impacts their academic performance. Additionally, the Organisation for Economic Co-operation and Development (OECD), in its PISA 2022 report, emphasizes the significance of cognitive skills, including working memory, as key factors in the academic achievements of secondary school students worldwide (OECD, 2023).

Despite the growing body of evidence, insufficient research exists in the Ecuadorian context that specifically analyzes the relationship between working memory and academic performance among adolescents aged 15 to 18 years. This age range is critical for cognitive growth and the development of academic skills. Such a gap is reflected in the low academic performance rates reported by the Ministerio de Educación de Ecuador (2023), highlighting the urgent need for studies that delve into the cognitive factors influencing adolescent learning.

In light of this scenario, the present study aims to investigate the relationship between working memory and academic performance among adolescents aged 15 to 18 in an educational institution located in the province of Guayas, Ecuador. The research intends to determine how the abilities related to the storage and temporary manipulation of information inherent in working memory correlate with academic performance across various subjects. The relevance of this research lies in its potential to provide empirical evidence that may inform the design of educational strategies aimed at strengthening cognitive processes, thereby potentially enhancing the academic performance and educational success of Ecuadorian adolescents.

Methodology

This study was conducted using a mixed-methods approach that combines a correlational quantitative component with an exploratory qualitative component. This methodological integration allowed for a comprehensive analysis of the relationship between working memory and academic performance in adolescents, ensuring the rigor and systematicity characteristic of scientific research. The selection of a correlational design for the quantitative aspect was based on prior research demonstrating its efficacy in examining links between cognitive and academic variables (Swanson et al., 2021), while the qualitative exploration provided greater insight into the educational context through the perspectives of teachers and counselors.

The study population consisted of students aged 15 to 18 enrolled in an educational institution in the province of Guayas, Ecuador. Simple random sampling was employed to select a final sample of 80 students, ensuring that all individuals had an equal probability of participation and enhancing the internal validity of the study (Dehn, 2021). Participation was voluntary and contingent upon signing an informed consent form, in line with the ethical recommendations of the American Psychological Association (APA, 2017).

To assess working memory, the Working Memory subtest from the Wechsler Intelligence Scale for Children and Adolescents (WISC-V) was utilized, a tool recognized for its international reliability and validity (Wechsler, 2021). Academic performance was measured using the official averages for Language and Literature, Mathematics, Natural Sciences, and English, provided by the institution at the end of the academic year. Additionally, semi-structured interviews were conducted with eight teachers and counselors, designed following the guidelines proposed by Flick (2018) for qualitative research in education. The interview protocol included ten open-ended questions aimed at exploring perceptions regarding the influence of working memory on adolescent learning and performance.

Data collection was carried out in two phases. Initially, working memory tests were administered individually in a controlled environment, with sessions lasting approximately 40 minutes per student. Subsequently, the interviews were conducted individually in private spaces provided by the institution, ensuring voluntariness and confidentiality.

Quantitative data were analyzed using IBM SPSS Statistics version 27, conducting descriptive analyses to characterize levels of working memory and academic performance, and Pearson correlation analyses to evaluate relationships between variables (Holmes & Gathercole, 2014). Qualitative data were processed through

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thematic categorization according to Flick's (2018) content analysis approach, enabling the identification of recurring patterns and perceptions in the teachers' responses.

Throughout the process, ethical principles of confidentiality, anonymity, and voluntariness were upheld according to the Code of Ethics by the APA (2017), ensuring the integrity and rights of participants and their legal guardians through the signing of informed consent.

Results

The findings of this research are presented below, centered on the main objective of determining the relationship between working memory and academic performance in adolescents aged 15 to 18.

Descriptive analysis of working memory

The average score obtained in the working memory test was 88.54 points (SD = 9.87), indicating that, on the whole, students fell within the average range. However, there was a wide variability in the results, with minimum scores of 70 and maximum scores of 112, demonstrating notable differences in cognitive abilities within the assessed group (see Table 1).

Table 1

Descriptive statistics for working memory

Variable	Mean	Standard Deviation	Minimum	Maximum
Working memory score	88.54	9.87	70	112

Descriptive analysis of academic performance

Regarding academic performance, average scores were calculated for the subjects of Language and Literature, Mathematics, Natural Sciences, and English. The results exhibited acceptable means, ranging from 7.85 to 8.15. Mathematics had the lowest mean score (7.85), followed by English (7.98), Natural Sciences (8.03), and Language and Literature (8.15). The standard deviations indicated moderate dispersion in the grades, reflecting some individual differences in performance (see Table 2).

Table 2

Descriptive statistics for academic performance

Subject	Mean	Standard Deviation	Minimum	Maximum
Language and Literature	8.15	0.75	6.5	9.8
Mathematics	7.85	0.88	6.0	9.6
Natural Sciences	8.03	0.82	6.2	9.7
English	7.98	0.79	6.3	9.5

Relationship between working memory and academic performance

Pearson correlation analysis revealed positive and statistically significant associations between working memory and academic performance in all four evaluated areas. The strongest correlation was found with Mathematics ($r = 0.612$, $p < 0.01$), followed by Language and Literature ($r = 0.587$, $p < 0.01$), Natural Sciences ($r = 0.563$, $p < 0.01$), and English ($r = 0.545$, $p < 0.01$). These results suggest that students with higher working memory capacity tend to perform better academically, particularly in subjects requiring greater information processing and reasoning (see Table 3).

Table 3

Correlations between working memory and academic performance

Variables	Correlation coefficient (r)
Working Memory and Language and Literature	0.587
Working Memory and Mathematics	0.612

Working Memory and Natural Sciences	0.563
Working Memory and English	0.545

Qualitative results: interviews with teachers

The semi-structured interviews conducted with eight teachers and counselors from the educational institution provided complementary quantitative information, offering qualitative insights into the impact of working memory on academic performance. The professionals emphasized that working memory is crucial for understanding instructions, active participation in class, and effectively solving tasks. They also noted that students who struggle to retain and manipulate information tend to exhibit lower academic performance, particularly in Mathematics and Language and Literature.

Furthermore, the educators highlighted the lack of institutional programs specifically aimed at strengthening working memory. However, they expressed a strong need for pedagogical strategies designed to enhance this cognitive function with the goal of improving learning outcomes and academic performance among adolescents.

Discussion

The results obtained from this research confirm the existence of a positive and significant relationship between working memory and academic performance in adolescents aged 15 to 18, aligning with theories and previous studies in educational psychology and cognitive neuroscience. This cognitive function, defined as the capacity to temporarily maintain and manipulate information, emerges as an essential process underpinning the complex learning required during adolescence, a period during which students face increasingly demanding cognitive challenges (Packiam et al., 2011; Baddeley, 2003).

A detailed analysis of the correlations revealed that the subjects most closely linked to working memory were Mathematics and Language and Literature. This is partly explained by the cognitive demands these disciplines impose: Mathematics requires the simultaneous processing of various data, active manipulation of numbers, and logical reasoning, all functions clearly associated with both verbal and visuospatial working memory (Swanson et al., 2021). In Language and Literature, working memory plays a fundamental role in reading comprehension by allowing students to retain segments of text to build coherent meaning, as well as facilitating thought organization and effective language use (Packiam et al., 2011; Baddeley, 2003).

The studies by Holmes and Gathercole (2014) reinforce this perspective by indicating that working memory directly affects the ability to process and retain information in both general educational contexts and specific domains such as reading comprehension and mathematical reasoning.

Insights gathered through the interviews with teachers and counselors provide a more contextualized understanding of the impact of working memory on the educational process. Limitations in this capacity were found to affect fundamental aspects such as the ability to retain instructions, maintain attention for prolonged periods, and engage with tasks of varying complexity. This qualitative perception supports and enriches the quantitative data, underscoring the finding that deficits in working memory significantly impact academic performance, particularly in subjects that demand high cognitive processing. Moreover, it identifies a gap in the local educational system, as there are currently no strategies or institutional programs aimed at enhancing this cognitive function.

Regarding the practical applicability of these findings, Dehn (2021) notes that interventions aimed at enhancing working memory through specific exercises and programs have been shown to improve academic performance and promote general cognitive skills. Implementing such programs in educational contexts that face challenges, like those investigated in this study, could provide a promising avenue to reduce disparities in learning and foster better academic outcomes.

However, certain inherent limitations must be acknowledged. The small sample size and its concentration within a single educational institution restrict the ability to generalize the results to broader and more diverse populations. Additionally, other relevant cognitive variables, such as attention, processing speed, or metacognitive skills—which likely interact with working memory and modulate its influence on learning—were not included. Future research should adopt an interdisciplinary approach with representative samples to deepen the understanding of the multiple factors that influence academic performance during adolescence in Ecuador.

Moreover, it is essential to consider how contextual and socio-emotional factors, including the school environment, pedagogical quality, and family support, interact with cognitive functions to determine educational success (Holmes & Gathercole, 2014). Thus, adopting comprehensive approaches that simultaneously address cognitive and socio-emotional dimensions could enhance learning and promote holistic student development.

Ultimately, the findings underscore the crucial role of working memory as a determining component of academic performance in adolescents. Its consideration in educational planning and teacher training emerges as an indispensable strategy for improving teaching and learning processes, particularly in contexts marked by evident educational challenges at the local level. Continued and expanded research across various domains and regions of the country will strengthen the foundational knowledge necessary to design effective educational policies and practices that support the cognitive and academic development of youth.

Conclusions

This research robustly confirmed the existence of a positive and significant relationship between working memory and academic performance among adolescents aged 15 to 18 in an educational institution in the province of Guayas, Ecuador. This finding reaffirms that working memory is an essential cognitive function for effective learning during adolescence, a period characterized by crucial cognitive changes and increasingly complex and diverse academic demands.

Statistical analyses indicated that students with greater capacities to retain and manipulate information in working memory achieved higher grades in key subjects such as Mathematics, Language and Literature, Natural Sciences, and English. Notably, the strongest correlation was observed in Mathematics, highlighting the importance of working memory for cognitive processes that involve simultaneous management of concepts, logical reasoning, and complex problem-solving. This suggests that strengthening this cognitive function could significantly enhance learning in areas of high cognitive demand.

On the other hand, the qualitative research conducted through interviews with teachers and counselors revealed that the institution studied lacks specific programs designed to develop working memory. This absence represents a significant gap in pedagogical practices, limiting the potential exploitation of this capacity to optimize learning. The teachers' perceptions regarding the direct impact of working memory on attention, following instructions, and active class participation underscore the necessity of implementing targeted educational interventions to enhance this function.

Finally, while the findings provide valuable insights, the research is limited by the small sample size and its focus on a single institutional context, complicating generalization to other realities. Moreover, it did not consider additional cognitive variables such as attention, processing speed, and metacognitive skills, which also influence academic performance. Therefore, it is recommended that future studies expand the sample and address these variables, along with the socio-emotional and pedagogical context, to design comprehensive strategies aimed at enhancing the cognitive and academic development of adolescents.

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