Working Memory and Academic Performance Among Fifth and Sixth-Graders

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Abstract

Background: Working memory (verbal/visuospatial) underpins cognitive processes in complex learnings like Arabic and mathematics. its relationship with academic achievement in Arab early education, critical for foundational skill development, remains underexplored.

Objective: This study examined associations between WM components (verbal/visuospatial capacity and processing) and academic performance (Arabic, mathematics, GPA) while exploring variations by topic-specific cognitive demands and assessing their relative impact.

Methodology: A correlational design was employed with a sample of 60 fifth- and sixth-graders (30 males, 30 females) randomly selected from two public schools. Standardized WM assessments included the Digit Span (forward/backward) test for verbal WM and the Corsi Block-Tapping (forward/backward) test for visuospatial WM. Academic scores were obtained from official school records for the preceding semester. Data were analysed using Spearman's correlation in SPSS v.26 due to non-normal distributions.

Results: Verbal memory capacity was positively correlated with performance in Arabic ($r=0.323$, $p=0.012$), but showed no significant relationship with mathematics ($r=0.138$, $p=0.295$) or overall GPA ($r=0.239$, $p=0.065$). Verbal processing demonstrated strong positive correlations with Arabic ($r=0.327$, $p=0.011$), mathematics ($r=0.555$, $p<0.001$), and overall GPA ($r=0.402$, $p=0.001$). Visuospatial memory capacity did not exhibit significant correlations (Arabic: $r=-0.025$, $p=0.847$; mathematics: $r=0.250$, $p=0.054$; overall GPA: $r=0.128$, $p=0.329$), whereas visuospatial processing was positively correlated with mathematics ($r=0.323$, $p=0.012$) but not with Arabic ($r=0.093$, $p=0.479$) or overall GPA ($r=0.175$, $p=0.181$).

Conclusion: The findings highlight that verbal processing supports academic performance across subjects, particularly in mathematics due to its reliance on verbal instructions, while visuospatial processing contributes to mathematical tasks. These results suggest the need for tailored educational interventions to enhance working memory components, with potential implications for improving academic achievement in Arabic-speaking contexts.

Keywords: working memory, phonological processing, visuospatial processing, academic performance, Arabic, mathematics.

Introduction

Working memory (WM) is a fundamental cognitive system that supports complex mental processes, characterized by the ability to temporarily retain and manipulate information during cognitive tasks such as problem-solving and language comprehension. This system transcends passive storage in short-term memory (STM) by actively engaging with information, making it a cornerstone of learning and academic performance (Baddeley & Hitch, 1974). It comprises four core components:

1. **The phonological loop**, which processes verbal and auditory information;
2. **The visuospatial sketchpad**, specialized for visual and spatial information;
3. **The central executive**, which coordinates cognitive processes and directs attention;
4. **The episodic buffer**, integrating information across components and linking WM to long-term memory (Baddeley, 2000).

These components rely on a neural network involving the prefrontal cortex for executive functions, the parietal lobe for visuospatial processing, and the hippocampus for binding WM to long-term memory (Fuster, 2002; Eriksson et al., 2015). Developmental disorders such as ADHD differentially impact these components, with studies indicating disruptions in processing routines that affect verbal and visuospatial information storage (Kaddouri & Alaoui-El-Amrani, 2025).

WM components play a pivotal role in language learning and linguistic performance, both generally and specifically in the context of Arabic. The phonological loop contributes to phonological awareness and vocabulary acquisition by storing and manipulating verbal information, a critical process for understanding spoken and written texts (Baddeley & Hitch, 1974). Meanwhile, the visuospatial sketchpad supports recognition of linguistic shapes and symbols, enhancing reading and writing skills. This is particularly salient in Arabic, where simultaneous processing of phonological and visual information is required due to its diacritical system and letter shape variations (Ibrahim, Eviatar, & Aharon-Peretz, 2002). The central executive regulates attention and allocates cognitive resources during language tasks, while the episodic buffer synthesizes information to form integrated linguistic representations (Miyake et al., 2000; Baddeley, 2000). Studies demonstrate that individuals with high WM capacity excel in comprehending complex texts (Cain, Oakhill, & Bryant, 2004). In Arabic, the language's unique features further amplify WM's role in facilitating rapid word recognition and linguistic comprehension (Abu-Rabia, 1997; El-Mir, 2018).

Working memory (WM) also plays a critical role in mathematical learning by retaining and manipulating numerical information during problem-solving, aiding in organizing solution steps and retaining intermediate results (Andersson & Lyxell, 2007). The phonological loop contributes to the retrieval of numerical sequences and verbal instructions, while the central executive directs attention and coordinates steps in complex tasks such as algebraic problems (Campbell, 2008; Miyake et al., 2000). Research indicates that WM deficits are associated with difficulties in understanding mathematical concepts, whereas children with high WM capacity demonstrate superior performance in mathematical tasks (Purpura et al., 2017). A study by Es-salmi (2024) further confirmed that WM supports information encoding and retrieval, while executive functions such as cognitive inhibition and flexibility enhance accuracy and strategy-switching abilities in mathematical contexts. WM participate to cognitive functioning, in this sense consistent findings linked it to reading skills (El-Mir, 2017, 2020, 2022; Naciri & El-Mir, 2019), reading comprehension (Bouayad & El-Mir, 2022), and academic achievement (El-Mir, 2019). Its capacity has also been shown to decline in some neurodevelopmental disorders, such as autism (Guennach & El-Mir, 2019) and specific developmental language disorders (Kriblou & El-Mir, 2021, 2024). WM is also affected by depression (Dahbi & El-Mir, 2020) and aging (El-Mir, 2021). It has also been proved that WM functioning is altered by emotional state (Bousbaiat & El-Mir, 2021; El-Mir, 2018). Moreover, cognitive training improves WM capacity in children with autism spectrum disorder (Sedjari

& El-Mir, 2021; Sedjari, El-Mir & Souirti, 2023), children with attention-deficit/hyperactivity disorder (Alaoui Belghiti & El-Mir, 2023), and children with dyslexia (Ammour & El-Mir, 2023). The effect of cognitive training on working memory has also been confirmed (El-Mir & Sedjari, 2022). Cognitive training contribute also to improvements in working memory performance in people with schizophrenia (El-Haddadi & El-Mir, 2022). Furthermore, WM is related to executive functions (Sedjari & El-Mir, 2025).

Generally, WM constitutes a foundational element for academic success across disciplines, supporting skills such as reading, writing, and problem-solving through information organization and analysis (Gathercole et al., 2006). Individuals with high WM capacity excel in assimilating diverse academic materials and managing multitasking—a vital ability in modern education (Cain, Oakhill, & Bryant, 2004; Pimperton et al., 2022). Conversely, cognitive load impacts WM efficiency: high intrinsic load reduces the phonological loop's capacity to retain verbal sequences, extraneous load diminishes the accuracy of the visuospatial sketchpad, and germane load fosters deep learning when instructional design is optimized (Sweller, 1988; Barrouillet et al., 2001; Logie et al., 1990). Sweller (1988) emphasizes that minimizing extraneous load enhances WM efficiency, thereby improving academic performance by directing cognitive resources toward comprehension and knowledge construction.

Despite extensive research on WM and academic performance, a gap remains in studying the correlations between the cognitive performance of WM components and academic achievement in Arabic language, mathematics, and overall performance. The study's problem lies in exploring how these components interact with learning demands in these domains, particularly given the cognitive challenges of Arabic. This raises two central questions: *Does high performance on WM tasks correlate with higher academic achievement among pupils?* and *How does the relationship between executive function components and academic achievement vary based on the domain-specific cognitive demands of each subject?* The study hypothesizes a positive relationship between WM component performance and academic achievement, with two operational hypotheses:

1. **H1**: Higher performance on WM tasks predicts better academic outcomes.
2. **H2**: The relationship between WM components and academic achievement varies according to the cognitive demands of each subject.

Method

Research Design

This study was designed as a correlational investigation to explore the relationship between pupils' academic performance and the cognitive performance of distinct working memory (WM) components: *phonological working memory* (capacity and processing) and *visuospatial working memory* (capacity and processing). A quantitative approach was employed, utilizing standardized cognitive and academic assessments to enable precise statistical analysis of variable relationships. The research specifically examined how WM components correlate with academic achievement in Arabic language, mathematics, and overall Grade Point Average (GPA).

Participants

The sample comprised 60 childrens (30 males, 30 females) aged 10–13 years, recruited from an elementary school. Participants were evenly distributed by gender and grade level (30 fifth-grade and 30 sixth-grade pupils) to ensure balanced demographic representation. Inclusion criteria required written consent from both participants and their parents, while pupils with documented learning difficulties or cognitive impairments were excluded to maintain sample homogeneity.

Measurement Tools

Standardized instruments were used to assess WM components and academic performance, selected for their established reliability and validity in prior studies:

Phonological WM Capacity: *Forward Digit Span Test* required participants to verbally repeat increasingly longer numerical sequences in the order presented.

Phonological WM Processing: *Backward Digit Span Test* assessed mental manipulation by requiring participants to reverse the order of presented numerical sequences.

Visuospatial WM Capacity: *Corsi Block Tapping Test (Forward)* measured the ability to replicate increasingly complex spatial sequences of tapped blocks.

Visuospatial WM Processing: *Corsi Block Tapping Test (Backward)* evaluated spatial manipulation by requiring participants to reverse the order of block-tapping sequences.

Academic Performance: Official school records provided scores for Arabic language, mathematics, and overall GPA from the first academic term.

Study Procedures

The study adhered to ethical and methodological standards through the following steps:

Approvals: Formal permissions were obtained from the Higher School of Teachers, Regional Academy of Education and Training, Regional Directorate of the Ministry of Education, and school administration.

Informed Consent: Written consent was secured from parents and participants after explaining the study's objectives and procedures.

Testing Environment: WM assessments were conducted individually in a quiet school setting to minimize distractions.

Phases:

- *Phase 1*: Phonological WM tests (Forward and Backward Digit Span).
- *Phase 2*: Visuospatial WM tests (Forward and Backward Corsi Block Tapping).

Data Collection: Academic scores were retrieved from official records at the end of the term. Data were entered into SPSS v26 for statistical processing.

Data Analysis

Data were analyzed using the following statistical methods:

Descriptive Statistics: Means and standard deviations summarized WM and academic performance scores.

Normality Tests: Non-normal data distribution (identified via Shapiro-Wilk tests) justified non-parametric analyses.

Inferential Statistics: *Spearman's rank correlation coefficients* assessed relationships between WM components (phonological capacity/processing, visuospatial capacity/processing) and academic outcomes (Arabic, mathematics, GPA).

Assumption Checks: All statistical assumptions (e.g., independence, linearity) were verified prior to analyses to ensure validity.

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Results

Table 1 Means and Standard Deviations of Academic Performance and Working Memory Components

Test	Min	Max	Raw Mean	Overall Mean	SD	N
Arabic Language	4.25	9.59	7.28	5	1.16	60
Mathematics	3.25	9.50	6.45	5	1.54	
Overall GPA	4.58	8.72	6.91	5	0.93	
Phonological Capacity	2	5	3.48	4	0.70	
Phonological Processing	1	4	2.35	4	0.80	
Visuospatial Capacity	2	5	3.68	4	0.72	
Visuospatial Processing	1	4	3.02	4	0.63	

Academic Performance

As shown in Table 1, pupils' mean score in **Arabic language** was 7.28/10 (SD = 1.16), with a range of 4.25–9.59. This relatively high mean reflects strong performance in linguistic skills (e.g., reading, writing, comprehension). The low standard deviation indicates homogeneous performance across childrens, with most scores clustered around the mean, suggesting minimal individual differences. The narrow range further supports this homogeneity, implying that the majority of pupils possess comparable language proficiency. This outcome may stem from effective Arabic teaching methodologies or the subject's reliance on familiar skills such as text processing and expression.

In **mathematics**, pupils achieved a lower mean score of 6.45/10 (SD = 1.54), with a wider range (3.25–9.50). The higher standard deviation reflects significant variability in performance: some pupils scored exceptionally well, while others struggled. The broad range underscores pronounced differences in mathematical abilities, readiness levels, or instructional quality. This variability likely arises from the complexity of mathematical concepts requiring advanced cognitive skills (e.g., logical reasoning, problem-solving), which pupils may not uniformly master.

The overall **GPA** averaged 6.91/10 (SD = 0.93), with a range of 4.58–8.72. This intermediate mean, situated between Arabic and mathematics scores, suggests balanced academic performance. The low standard deviation indicates stable GPA distribution, with most pupils performing close to the mean. The narrower range compared to mathematics highlights that overall academic disparities are less pronounced than subject-specific variations. This stability may result from averaging across subjects, which mitigates extreme differences.

Cognitive Indicators

Phonological Working Memory Capacity

Pupils scored a mean of 3.48 on the Forward Digit Span Test, close to the test's overall mean of 4, with a low standard deviation (SD = 0.70) and a range of 2–5. This moderate performance reflects average ability to store and process auditory information—a foundational skill for language tasks such as reading and writing. The low SD indicates homogeneity in this ability across pupils, with most scores clustering around the mean. The limited range suggests minimal variability, though opportunities for improvement exist, particularly for pupils scoring at the lower end.

Phonological Working Memory Processing

For the Backward Digit Span Test, the mean score was 2.35, below the overall mean of 4, with a higher

SD of 0.80 and a range of 1–4. The lower mean highlights difficulties in manipulating linguistic sounds and symbols, critical for text comprehension and analysis. The higher SD and broader range reflect notable variability, with some pupils achieving maximum scores while others performed poorly. This disparity may stem from differences in individual linguistic abilities or prior training in such skills.

Visuospatial Working Memory Capacity

On the Forward Corsi Block Tapping Test, pupils achieved a mean of 3.68 (SD = 0.72; range = 2–5). This relatively strong performance indicates robust ability to store and process visuospatial information, essential for spatially demanding tasks like geometry. The low SD and moderate range suggest homogeneous abilities among pupils, with no extreme outliers, pointing to a solid foundational skill set in this domain.

Visuospatial Working Memory Processing

For the Backward Corsi Block Tapping Test, the mean score was 3.02 (SD = 0.63; range = 1–4). This moderate-to-good performance reflects competent visuospatial manipulation skills, which support tasks requiring spatial reasoning. The low SD and narrow range indicate consistent abilities across pupils, with limited individual differences.

Table 2 Spearman's Correlation Coefficients Between Phonological Working Memory Capacity and Academic Performance in Arabic, Mathematics, and Overall GPA

Test	Arabic Language	Mathematics	Overall GPA
Forward Digit Span	0.323*	0.138	0.239
p-value	0.012	0.295	0.065
Sample Size (N)	60	60	60
Relationship Type	Moderate positive (p < 0.05)	No correlation	No correlation

Table 3 Spearman's Correlation Coefficients Between Phonological Processing and Academic Performance in Arabic, Mathematics, and Overall GPA

Variable	Arabic Language	Mathematics	Overall GPA
Backward Digit Span	0.327*	0.555**	0.402**
p-value	0.011	0.000	0.001
Sample Size (N)	60	60	60
Relationship Type	Moderate positive (p < 0.05)	Strong positive (p < 0.01)	Moderate positive (p < 0.01)

The findings in Table 2 reveal a moderate positive correlation between phonological working memory capacity and performance in Arabic language (=0.323, p=0.012, p< 0.05). This suggests that pupils with stronger abilities to retain auditory sequences (e.g., words or sentences) achieve higher Arabic scores, likely due to the subject's reliance on skills such as reading comprehension, semantic analysis, and dictation, all of which demand auditory information retention during processing. Conversely, phonological working memory capacity showed no significant correlation with mathematics performance (rs =0.138, p=0.295, p>0.05), indicating that this skill does not directly influence mathematical problem-solving, which relies more on logical reasoning and spatial visualization. For overall GPA, the correlation coefficient was rs=0.239 (p=0.065), approaching but not reaching statistical significance, implying a limited impact of phonological capacity on comprehensive academic achievement due to the diverse subjects contributing to GPA.

As shown in Table 3, phonological processing demonstrated significant positive relationships with academic performance. In Arabic language, the correlation was rs=0.327 (p=0.011, p<0.05), reflecting that pupils with stronger phonological manipulation skills (e.g., segmenting words into syllables or linking sounds to letters) performed better. This aligns with Arabic's demands, such as decoding written texts and spelling, which require precise sound analysis. For example, writing the word "استعمال" necessitates breaking it into syllables (e.g., *is-ti-māl*). In mathematics, phonological processing showed a robust correlation (rs=0.555, p=0.000, p<0.001), highlighting its role in solving verbal problems like *"Mohammed bought 4 books and 3 pens. What is the total?"*, where understanding verbal instructions is critical. For GPA, the correlation was rs=0.402 (p=0.001, p<0.01), confirming that phonological processing positively impacts overall academic achievement by supporting multiple subjects.

Hypothesis Testing

Hypothesis 1 (*Higher WM performance predicts better academic outcomes*) is supported: Phonological processing showed strong positive correlations with Arabic (rs0.327, p=0.011), mathematics (rs=0.555, p=0.000), and GPA (rs0.402, p=0.001), while phonological capacity only moderately correlated with Arabic (rs=0.323, p=0.012) and had no effect on mathematics or GPA.

Hypothesis 2 (*WM components correlate with academic performance based on subject-specific demands*) is confirmed: Phonological capacity primarily impacts Arabic, which relies on auditory storage, whereas phonological processing supports both Arabic and mathematics, particularly in tasks requiring verbal instruction analysis (e.g., word problems).

These results suggest that enhancing phonological working memory components could improve academic performance, with interventions tailored to the cognitive demands of each subject.

Table 4 Spearman's Correlation Coefficients Between Visuospatial Working Memory Capacity and Academic Performance in Arabic, Mathematics, and Overall GPA

Variable	Arabic Language	Mathematics	Overall GPA
Visuospatial Capacity	-0.025	0.250	0.128
p-value	0.847	0.054	0.329
Sample Size (N)	60	60	60
Relationship Type	No correlation	No correlation	No correlation

Table 5 Spearman's Correlation Coefficients Between Visuospatial Processing and Academic Performance in Arabic, Mathematics, and Overall GPA

Variable	Arabic Language	Mathematics	Overall GPA
Visuospatial Processing	0.093	0.323*	0.175
p-value	0.479	0.012	0.181
Sample Size (N)	60	60	60
Relationship Type	No correlation	Moderate positive (p < 0.05)	No correlation

As shown in Table 4, visuospatial working memory (WM) capacity exhibited no statistically significant correlation with academic performance in Arabic language (rs=−0.025, p=0.847, p>0.05). This reflects that this skill does not influence achievement in a subject primarily reliant on linguistic competencies, such as text comprehension or dictation, which do not require visual-spatial reasoning. In mathematics, the correlation approached but did not reach significance (rs=0.250, p=0.054), suggesting a weak positive trend potentially linked to tasks like geometric visualization or graph analysis, though the effect size was insufficient to confirm a relationship. For overall GPA, the correlation was rs=0.128 (p=0.329, p>0.05), confirming no notable impact of visuospatial capacity on comprehensive academic achievement, likely due to the diversity of subjects contributing to GPA.

According to Table 5, visuospatial processing demonstrated a moderate positive correlation with mathematics performance (rs=0.323, p=0.012, p<0.05). This confirms that pupils with stronger visuospatial manipulation skills (e.g., mentally rotating shapes or analyzing spatial relationships) achieve higher mathematics scores, particularly in tasks requiring geometric reasoning (e.g., solving triangle angle problems or coordinate systems). Conversely, no significant correlation was found with Arabic language (rs=0.093, p=0.479, p>0.05), consistent with the subject's focus on verbal skills like reading and writing. For overall GPA, the correlation was rs=0.175 (*p*=0.181, p>0.05), indicating that visuospatial processing impacts only domain-specific performance.

Hypothesis Testing

Hypothesis 1 (*Higher visuospatial WM performance predicts better academic outcomes*) is **partially supported**. While visuospatial processing showed a moderate positive correlation with mathematics (rs=0.323, p=0.012), visuospatial capacity had no significant relationships with Arabic (rs=−0.025, p=0.847), mathematics (rs=0.250, p=0.054), or GPA (rs=0.128, p=0.329).

Hypothesis 2 (*Visuospatial WM components correlate with academic performance based on subject-specific demands*) is **strongly confirmed**. The lack of correlations with Arabic (rs=−0.025, *p*=0.847 for capacity; rs=0.093, p=0.479 for processing) aligns with its minimal visuospatial demands. Conversely, the significant correlation between visuospatial processing and mathematics (rs=0.323, p=0.012) underscores its relevance to spatially demanding tasks.

These findings highlight that visuospatial WM's impact is contingent on subject-specific cognitive requirements, emphasizing the need for targeted educational interventions to enhance these skills in mathematics.

Discussion

This study aimed to explore the relationship between components of working memory (verbal and visuospatial) and academic performance in Arabic and mathematics, while investigating how these relationships vary based on the cognitive demands of each subject. Additionally, it sought to provide recommendations for enhancing academic achievement through targeted interventions.

Verbal Working Memory Capacity and Processing

The findings indicate that verbal working memory (VWM) capacity exhibits a moderate positive correlation with performance in Arabic language (p<0.05), aligning with prior research by Cain et al. (2004), who emphasized its role in text comprehension and verbal reasoning—skills critical for Arabic, which requires retaining phonological sequences during reading or dictation. This correlation likely reflects the need to temporarily store phonological information to process complex sentences, as noted by Abu-Rabia (1997) in the context of Arabic diacritics. In contrast, the lack of significant correlation with mathematics ($p>0.05$) aligns with Andersson & Lyxell's (2007) assertion that mathematical tasks depend more on spatial reasoning and logical analysis, minimizing the role of verbal storage.

Verbal processing, however, demonstrated robust correlations with Arabic ($p<0.05$), mathematics ($p<0.001$), and overall GPA ($p<0.01$). These results reinforce Baddeley & Hitch's (1974) model of the phonological loop in supporting phonological awareness and vocabulary acquisition—processes vital for decoding Arabic texts, as highlighted by Ibrahim et al. (2002). The strong association with mathematics, though initially unexpected, parallels Campbell's (2005) observations on the importance of verbal instruction retrieval in word problems requiring linguistic sequencing prior to calculation. This underscores verbal processing's broader role in organizing cognitive resources, consistent with Lonigan et al.'s (2009) findings on its cross-disciplinary impact.

Visuospatial Working Memory Capacity and Processing

Visuospatial working memory (VSWM) capacity showed no significant correlations with Arabic language ($p>0.05$), mathematics ($p>0.05$), or overall GPA ($p>0.05$). This aligns with Ibrahim et al.'s (2002) assertion that Arabic text processing relies on the integration of phonological and visual letter features rather than pure spatial storage. The near-significant trend in mathematics ($p=0.054$) partially supports Purpura et al.'s (2017) findings on the role of visuospatial skills in early numerical reasoning, though the limited effect here may reflect the scarcity of spatially demanding tasks in the studied curriculum.

In contrast, visuospatial processing exhibited a moderate positive correlation with mathematics ($p<0.05$), consistent with Es-salmi's (2024) emphasis on executive functions, including spatial manipulation, in solving geometric or spatially complex problems. This underscores the visuospatial sketchpad's role in organizing visual information, as noted by Ibrahim et al. (2002) in symbol recognition tasks. The lack of correlation with Arabic ($p>0.05$) resonates with El-Mir's (2018) conclusion that Arabic reading depends more on phonological integration than spatial visualization.

Conclusion

These findings affirm the multifaceted nature of working memory (WM) as described by Baddeley (2000), where distinct components differentially support cognitive tasks. The results align with Just and Carpenter's (1992) proposition that WM capacity serves as a predictive indicator for success in tasks requiring precise processing, such as Arabic language, while verbal and visuospatial processing demonstrate broader impacts extending to mathematics. This corroborates Miyake et al.'s (2000) model of the central executive in coordinating cognitive resources. The study underscores the necessity of designing educational interventions that target specific WM components to enhance subject-specific performance, particularly given the unique cognitive challenges of Arabic literacy highlighted by Trabelsi et al. (2023). Future research should incorporate more diverse tasks to further elucidate these relationships.

Recommendations

To leverage these findings, the following evidence-based strategies are proposed:

1. **Verbal Skill Enhancement**: Integrate activities like word repetition, text summarization, or phonological segmentation exercises to bolster Arabic literacy, given the strong link between verbal processing and performance.

2. **Mathematical Problem-Solving**: Train children's to decode verbal instructions in word problems through sentence analysis games or group discussions, fostering verbal processing skills critical for linguistic-mathematical tasks.
3. **Visuospatial Training**: Introduce geometry puzzles, graph interpretation tasks, or mental rotation exercises to strengthen visuospatial processing, which showed significant ties to mathematics performance.
4. **Flexible Programs**: Develop adaptive curricula that align with domain-specific cognitive demands, ensuring alignment between WM components and subject requirements. Further research is needed to evaluate the efficacy of these interventions across diverse educational contexts.

Study Limitations

1. **Sample Size and Context**: The limited sample size and geographic specificity (e.g., a single elementary school) constrain the generalizability of results to broader educational or cultural settings.
2. **Subject Focus**: Restricting analysis to Arabic and mathematics overlooks potential WM influences on other subjects (e.g., science, social studies).
3. **Task Diversity**: The study did not account for intra-subject task variations (e.g., reading vs. writing in Arabic), which may affect the interpretation of WM-academic relationships.
4. **Measurement Constraints**: Reliance on specific WM tasks (e.g., digit span, Corsi blocks) may not fully capture complex interactions between WM components (e.g., episodic buffer functionality).
5. **External Factors**: Uncontrolled variables such as student motivation, instructional quality, or socioeconomic background could confound academic performance outcomes.

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