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# Supporting Children's Working Memory Through Instructional Support in Primary School: A Microtrial Study

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**Abstract**

Working memory (WM) is crucial for learning and academic success, emphasizing the need for effective theory- and practice-informed interventions supporting children with poor WM. Given limited transferable effects, recent research stresses the importance of context, focusing on malleable environmental factors like teacher–student interaction. This study uses a microtrial approach to explore the effects of teacher-provided instructional support on children's observable WM-related problematic behavior. The experimental group ($n$ = 35, 42.9% girls, Mage = 8.37, SDage = 1.66) received targeted instructional support, while the control group ($n$ = 32, 40.6% girls, Mage = 8.67, SDage = 2.03) received teaching as usual. Pre- and post-intervention comparisons examined changes in students' WM behavior. The four-week intervention included five strategies derived from a systematic review and a qualitative study, building on teachers' existing practices. Findings revealed a significant time × condition interaction, with reduced WM-related problematic behavior in the experimental group, showing medium to large effect sizes ($\eta_p^2$ = 0.08–0.20). Improvements were noted in classroom behavior and the home environment, as reported by parents blinded to the condition. This study contributes to the causal evidence base indicating that targeted instructional support can reduce WM-related challenges and highlights the potential of brief, teacher-provided classroom interventions.

**Keywords:** working memory; teacher–student interaction; instructional support; intervention; microtrial



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## 1. Introduction

### *1.1. Working Memory*

#### 1.1.1. Conceptualization and Development

Working memory (WM), a core executive function (EF), is responsible for temporarily storing, updating, and manipulating verbal and visuospatial information needed to perform tasks (Baddeley, 2012; Diamond, 2012; Shah & Miyake, 1996). It is closely linked to attention, requiring focus on relevant information while filtering out distractions (Cowan, 2000; Eriksson et al., 2015; Oberauer, 2019), and underpins complex cognitive processes, including decision-making, planning, problem-solving, and reasoning (Cowan, 2022; Karr et al., 2018; Wiley & Jarosz, 2012). In addition, WM enables language processing, accurate instruction-following, and knowledge retention, all important for learning and social development (de Wilde et al., 2015; Jaroslawska et al., 2016; Pauls & Archibald, 2022).

WM development starts in infancy, rapidly progresses in preschool years, undergoes substantial and more gradual changes during childhood, and slows during adolescence (Ahmed et al., 2022; Gómez et al., 2018). Such a developmental curve aligns with changes in brain structures, including cortical thinning in the superior parietal cortex, prefrontal cortex maturation, synaptic pruning, and myelination (Kharitonova et al., 2013; Kolk & Rakić, 2021; Zhong et al., 2014). Behavioral and neuroimaging research findings suggest that during early and middle childhood, marked by high neural and cognitive plasticity, children's development is influenced by both innate developmental processes and, although less studied, environmental factors (Blair, 2016; Thompson & Steinbeis, 2020; Zelazo & Carlson, 2020).

#### 1.1.2. Academic Performance and Social Functioning

WM plays a foundational role in primary school learning, supporting children's ability to manage complex tasks, follow instructions, and interact effectively in classroom environments (Cowan, 2022; Orson et al., 2020). Meta-analyses consistently link WM to academic achievement, particularly in mathematics and reading (Cortés Pascual et al., 2019; Spiegel et al., 2021). Although most findings are correlational, early intervention studies indicate that improving WM can positively influence learning outcomes, especially for children with cognitive vulnerabilities (J. Holmes & Gathercole, 2013; Oldrati et al., 2020; Passarotti et al., 2020; Veloso & Ty, 2021). Recent theoretical and empirical work further indicates a bidirectional relationship, suggesting that successful engagement in cognitively demanding tasks can also strengthen WM over time (Miller-Cotto & Byrnes, 2019; Peng & Kievit, 2020; Sankalaite et al., 2023b; Schmitt et al., 2017). These findings point to a cycle of positive reinforcement in which early WM capacity facilitates academic success, which, in turn, promotes further WM development.

In parallel, WM significantly contributes to children's social functioning and classroom behavior (Best et al., 2009; Miller-Cotto & Byrnes, 2019; Vandenbroucke et al., 2018). Stronger WM capacities are associated with better emotion regulation, social competence, and peer relationships, whereas deficits are linked to peer rejection, aggression, and difficulties with conflict resolution (de Wilde et al., 2015; Jaroslawska et al., 2016; McQuade et al., 2013; Pauls & Archibald, 2022). Importantly, this relationship appears bidirectional: WM difficulties may lead to social withdrawal or exclusion, while negative social experiences can undermine cognitive engagement and constrain WM development. In contrast, supportive interactions with teachers and peers may help foster WM over time (Buhs et al., 2006; de Wilde et al., 2015; Lecce & Bianco, 2018; Tobia et al., 2016; Will et al., 2015). Although few interventions directly target WM as a pathway to social development, enhancing cognitive capacities may indirectly support socio-emotional growth, in line with social information processing theory (Crick & Dodge, 1994). Given WM's central role in both academic and social domains, numerous attempts have been made to strengthen WM in primary school children (Diamond & Ling, 2016; Rowe et al., 2019).

#### 1.1.3. Interventions and Training Programs

A broad range of interventions has aimed to enhance children's WM, though with mixed results. Most prominently, direct WM training programs (often computer-based, such as Cogmed (Klingberg et al., 2005)) focus on the execution of tasks with high WM demands and assume that repeated and systematic practice with increasing difficulty can lead to improvements in trained skills (Melby-Lervåg & Hulme, 2013; Strobach & Karbach, 2016). While early findings reported small-to-moderate short-term improvements on untrained WM tasks ('near-transfer' or 'intermediate-transfer'), more recent reviews and meta-analyses have raised questions about the durability and significance of these effects. These studies suggest that both near- and far-transfer effects, along with sustained improvements, are either limited or negligible (Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016; Sala & Gobet, 2017). These conclusions hold across various age groups, including, but not limited to, primary school children.

This lack of transferable and durable effects prompted a shift toward alternative, often indirect, training approaches (Dunning & Holmes, 2014; Dunning et al., 2013; Randall & Tyldesley, 2016). Interventions incorporating physical activity or mindfulness have shown weak-to-moderate gains in WM (Angelopoulou & Drigas, 2022; Chen et al., 2018; Hsieh et al., 2018), but again, evidence for broader transfer remains inconsistent (Diamond & Ling, 2016; Rowe et al., 2019). In response, recent research has begun exploring interventions embedded in children's everyday learning environments, particularly through adaptations in classroom practices (Dunning & Holmes, 2014). Although still scarce, studies in which teacher behaviors are the primary target, rather than student behavior, suggest small, positive effects of emotionally and instructionally supportive teaching on children's WM (J. Holmes & Gathercole, 2013; Zelazo et al., 2016; for a review, see Sankalaite et al., 2021). Such interventions primarily train teachers to modify educational environments to better support children, leading to short-term gains and potentially longer-lasting improvements, when effectively implemented (e.g., Ansari & Pianta, 2018; Elliott et al., 2010).

Rather than aiming to improve WM capacity directly, these ecologically valid approaches focus on reducing cognitive load and tailoring instruction to better support children with weaker WM, thereby facilitating learning (Coleman et al., 2019; de Weerdt et al., 2012; Gathercole et al., 2008; Hultberg et al., 2018). While preliminary findings on teacher-provided instructional support are promising, causal evidence remains limited. The field still lacks clarity on which intervention components are most effective, as existing studies vary widely in outcomes, intensity, and implementation fidelity (Rowe et al., 2019). Nonetheless, understanding how teachers can shape the learning environment to support WM functioning offers a promising and underexplored direction for targeted, sustainable classroom-based interventions.

### *1.2. Teacher–Student Interaction*

#### 1.2.1. Domains of Support

Interactions with teachers can be conceptualized at two levels: the dyadic teacher–student relationship (TSR) and classroom-wide teacher–student interaction (TSI). While TSR has been associated with children's WM/EF and school readiness (Graziano et al., 2015; for a review, see Emslander et al., 2025) and may be instrumental for effective classroom-level support (Crosnoe et al., 2010; Nguyen et al., 2020), classroom-level interventions offer broader and more efficient reach, and align with previous EF-focused intervention efforts (Verschueren & Koomen, 2012).

The Teaching Through Interactions (TTI) framework (Hamre & Pianta, 2007; Hamre et al., 2013) identifies three broad domains of TSI: emotional support, classroom organization, and instructional support. These domains collectively shape the learning environment and have been linked to students' cognitive outcomes, including WM (Downer et al., 2010; Hamre et al., 2014; Vandenbroucke et al., 2018). Emotional support, grounded in attachment theory (Bowlby, 1969) and self-determination theory (Deci & Ryan, 1985), creates a nurturing environment and, in turn, promotes engagement and reduces stress—key conditions for optimal WM functioning. Classroom organization, guided by cognitive load theory (Sweller, 1988), reduces cognitive load, allowing students to focus more on new information, thereby supporting WM. Instructional support draws on sociocultural theory (Vygotsky, 1978), using scaffolding and open-ended questioning to guide learners within their zone of proximal development, and on social learning theory (Bandura, 1978), which emphasizes learning through observation and imitation, to support understanding and WM. Overall, the TTI framework emphasizes that how teachers interact with students, rather than what they teach, is crucial for fostering learners' social, academic, and cognitive development.

#### 1.2.2. Evidence for the Interplay Between WM and TSI

Although still limited, existing evidence highlights a complex interplay between WM and TSI. A meta-analysis by Vandenbroucke et al. (2018) found small-to-medium but significant effects, with stronger associations between appropriate support and minimized cognitive deficits in vulnerable and disadvantaged children, suggesting that supportive classroom interactions may mitigate cognitive vulnerabilities in primary school children (Vandenbroucke et al., 2017; for a review, see Rakesh et al., 2024). Furthermore, a systematic literature review (Sankalaite et al., 2021), exploring EF-focused interventions that manipulated TSI, implemented in pre-school and primary school, found that instructional support was most utilized and showed, somewhat consistently, a small positive effect on children's WM outcomes. This focus likely reflects the view that instructional practices are easier to observe, assess, and connect to student outcomes as they are closely tied to curriculum and learning goals and that improving these practices is central to teacher development and classroom quality (Ansari & Pianta, 2018; Elliott et al., 2010; R. Pianta et al., 2017). A recent qualitative study (Sankalaite et al., 2023a) confirmed that primary school teachers view instructional support as directly improving children's WM, classroom organization as offering indirect support, and emotional support as not specifically targeting WM-related difficulties (but see a review by Cumming et al., 2019).

The reviewed studies highlighted strategies often included in successful programs, but empirical evidence for their impact on WM is still scarce despite strong theoretical justification. Scaffolding was identified as a central approach, though it is more accurately understood as an underlying mechanism supporting specific instructional strategies. Feedback played a vital role in bridging the gap between current and desired performance, clarifying learning objectives, and fostering cognitive processing and self-regulation—thereby strengthening WM (Ansari & Pianta, 2018; Davis et al., 2013; Hattie, 2008; Hattie & Timperley, 2007; R. Pianta et al., 2017; Wolf et al., 2018). Prompting provided guidance before undesired behavior occurred, functioning as a preventative method and offering gentle reminders that aid recall, sequencing, and task management to facilitate WM (Ennis et al., 2012; Faul et al., 2011; Moore et al., 2018; Shabiralyani et al., 2015). Clearly defined academic rules were also effective, helping teachers structure instruction and encouraging students' reflection and responsibility (Alter & Haydon, 2017; Ingemarson et al., 2019; Simonsen et al., 2008). Modeling, through observation and imitation, minimized errors and built confidence by allowing students to practice successfully, supporting WM via active engagement (Ansari & Pianta, 2018; R. Pianta et al., 2017; Sander & de la Fuente, 2020). Finally, encouraging critical thinking promoted problem-solving and selective attention by engaging skills such as hypothesizing and comparing, further reinforcing WM (Massa, 2014; Paul & Elder, 2019). Collectively, these strategies show potential in enhancing children's WM, though it remains uncertain whether modifications in teacher behavior consistently translate into changes in WM-related classroom behavior.

### 1.3. Current Study

This study addresses the causal gap in understanding how teacher classroom practices shape children's WM by adopting a microtrial approach—a focused, mechanism-driven alternative to broad-scope randomized controlled trials (RCTs) (Howe et al., 2010). Unlike RCTs, microtrials test and isolate the short-term effects of discrete intervention components within real-world contexts, allowing for greater internal validity and ecological relevance (Hornstra et al., 2022). In doing so, the design offers a cost-effective method to link specific classroom strategies to children's learning and behavior outcomes.

This study examines whether instructional support can reduce WM-related problematic behavior in primary school children in Flanders (Belgium). WM difficulties often manifest as observable behaviors, such as inattentiveness, difficulty following instructions, or task disorganization. Teacher-rated WM behavior serves as the primary outcome, assessing the intervention's practical value in improving daily classroom functioning. This study also examines whether improvements observed from teacher-provided instructional support are reflected in parent-rated WM behavior observed in the home environment, providing evidence of transfer across contexts and offering insights into the underlying mechanism—whether instructional support directly enhances WM capacity or indirectly improves functioning by optimizing the learning environment and reducing WM demands. Performance-based WM tasks serve as a secondary outcome, enabling exploratory analysis of whether behavioral change extends to cognitive outcomes (Miyake et al., 2000).

This study hypothesizes (1) a greater reduction in WM-related problematic behavior from pre- to post-intervention in the experimental (intervention) group than in the control (teaching-as-usual) group, reflected in a significant time × condition interaction (Diamond & Ling, 2016). It also explores (2) whether improvements transfer to performance-based WM, and (3) whether larger effects occur among children with initially most problematic WM-related behavior (Diamond & Ling, 2016).

If effective, this design can inform future microtrials across the domains of the TTI framework (i.e., emotional support, classroom organization, instructional support), further investigating how targeted teacher practices enhance classroom-based WM (see study protocol of Pollé et al., 2025).

## 2. Materials and Methods

### 2.1. Participants

Sixty-seven teacher-child–parent triads participated: 35 in the experimental group and 32 in the control group. Group assignment was stratified by grade and gender to ensure balance across conditions. Most teachers were female (92.5%), aged 24–53 years (M = 36.34, SD = 7.69), with 3–33 years of experience (M = 13.89, SD = 7.87). In Belgium, each primary school classroom is generally assigned a main teacher for one academic year, and occasionally a part-time teacher, with the main teacher responsible for most subjects. Specialized subjects, such as physical education and art, are usually taught by subject-specific teachers. For this study, only one teacher per classroom participated. No significant differences were found between conditions with respect to the gender and age of both teacher and child, teachers' experience (see Table 1), and teachers' current positions (e.g., full-time teacher, part-time teacher; see Table S1 in Supplementary Materials. Children (ages 6–12, grades 1–6) were eligible if they attended regular primary school and displayed WM-related difficulties. The sample included 41.8% girls and 58.2% boys, evenly distributed across grades (7–16 in each). One parent per child participated, regardless of family structure. Main demographics are provided in Table 1; full details in Tables S1–S3.

**Table 1.** Socio-Demographic Information of the Participating Teachers and Children.

| Variables | Total $n$ (%) | Condition: Experimental $n$ (%) | Condition: Control $n$ (%) | Fisher's Exact Test $p$ | | |
|---|---|---|---|---|---|---|
| Teacher gender | | | | 0.185 | | |
| Male | 5 (7.5%) | 1 (2.9%) | 4 (12.5%) | | | |
| Female | 62 (92.5%) | 34 (97.1%) | 28 (87.5%) | | | |
| Child gender | | | | 1.00 | | |
| Male | 39 (58.2%) | 20 (57.1%) | 19 (59.4%) | | | |
| Female | 28 (41.8%) | 15 (42.9%) | 13 (40.6%) | | | |
| | | | | Independent samples $t$-test | | |
| Teacher age | M (SD) | M (SD) | M (SD) | $t$ | $df$ | $p$ |
| Age (in years) * | 36.34 (7.69) | 37.54 (6.94) | 34.93 (8.37) | 1.37 | 63 | 0.174 |
| Teaching experience (in years) * | 13.89 (7.87) | 14.69 (7.30) | 12.97 (8.52) | 0.88 | 63 | 0.384 |
| Child age | M (SD) | M (SD) | M (SD) | $t$ | $df$ | $p$ |
| Age (in months) ** | 102.27 (22.19) | 100.45 (19.97) | 104.03 (24.36) | −0.62 | 57 | 0.540 |

*Note:* * Two teachers did not provide this information; ** data for two children was not provided (by the parents).

Sample size justification. A power analysis conducted with G*Power (version 3.1) indicated that at least 38 participants per condition were required for a repeated measures ANOVA, assuming small-to-medium effect sizes (f = 0.15), a correlation among repeated measures of 0.75, power of 0.80, and $\alpha = 0.05$. Allowing for an anticipated attrition rate of 10%, the recruitment target was set at 42 participants per condition, yielding a total sample of 84.

### 2.2. Procedure

The study was approved by the Social and Societal Ethics Committee of KU Leuven (G-2020-1699-R4). The larger research project will investigate how different dimensions of TSI can influence primary school students' WM and related behavior. For full methodological details on the theoretical rationale, intervention, and participant recruitment, see the published protocol of Pollé et al. (2025).

Study timeline. This study consisted of four phases: pre-screening phase, pre-intervention phase, intervention phase, and post-intervention phase.

Recruitment and pre-screening. Teachers from Flemish primary schools were recruited via email and social media. After providing informed consent, both teachers completed a screening instrument adapted from the Behavior Rating Inventory of Executive Function (BRIEF-2; Gioia et al., 2015; Huizinga & Smidts, 2020). Children scoring ≥5 on both frequency and severity on ≥4 of 8 items were considered displaying WM-related problematic behavior and were pre-selected. Teachers distributed information letters and consent forms to parents, who, upon consenting, completed the adapted BRIEF-2 to assess the child's WM-related behavior at home. Children were confirmed eligible based on both of these ratings. One child per teacher was selected due to feasibility constraints, as the intervention required intensive monitoring of WM-related behaviors. While designed as a classroom-level approach, the focus was on a single student with poor WM for whom the impact was expected to be most pronounced. The participant flow is presented in Figure S1 (Supplementary Materials).

Pre-intervention phase (T0). Once the participant selection was completed, teachers completed socio-demographic questionnaire and the adapted Classroom Assessment Scoring System (CLASS; R. C. Pianta et al., 2008); children—the digit recall subtest of the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V; Wechsler, 2014) to assess verbal WM, and the Corsi block tapping test (Corsi, 1972) for visuospatial WM; parents completed a socio-demographic questionnaire. Schools were randomized by condition to prevent contamination.

Intervention phase. Teachers in the experimental group received training in five instructional support strategies. After getting familiar with the intervention sheets and completing a short knowledge quiz, they participated in a coaching session with trained coaches specialized in EF and teacher training. Target WM-related behaviors were identified through functional analysis acting as the primary focus of the intervention. Together with the coach, teachers completed an intervention plan, reflecting on how the five trained strategies could improve WM-related problematic behavior. The coach played an important role in adapting the strategies to each teacher's classroom context and teaching style, ensuring that the intervention was tailored and doable. Teachers were instructed to apply these strategies classroom-wide to the best of their ability, each time the selected student demonstrated WM-related problematic behaviors, and avoid using other-than-trained strategies for four weeks. This duration reflects typical short-term interventions suited to detecting behavioral changes and aligns with established ranges for effective, skill-based strategies (Durlak et al., 2011; Hornstra et al., 2022; Magnúsdóttir et al., 2025). Although the intervention was designed to be implemented by a single teacher per classroom, part-time teachers were briefed on the intervention plan to ensure awareness and classroom consistency. However, they did not actively deliver the intervention, allowing observed WM changes to be attributed specifically to the trained teacher. During the four-week implementation, teachers completed weekly entries via the m-Path application (www.m-Path.io), rating the extent of strategy use and reporting any use of untrained strategies. At the two-week midpoint (T1), teachers re-rated the four WM-related behaviors using the app. If both target behaviors remained problematic (a score $\geq 5/10$ on both frequency and severity), the intervention focus stayed the same; otherwise, the remaining two behaviors became the new targets, with a revised functional analysis and intervention plan developed collaboratively.

Post-intervention phase (T2). After the four-week intervention, teachers completed a follow-up CLASS-based questionnaire as a manipulation check, expecting increased use of instructional support (but not organizational or emotional support) in the experimental group. All other pre-intervention measures were re-administered to teachers and children (excluding socio-demographics), and teachers re-rated the identified WM-related behaviors using the m-Path application. To reduce informant (or expectancy) bias, parents—blind to the intervention condition—also rated these behaviors, enabling triangulation across home and school environments and strengthening validity.

After the study, teachers of the control group received full intervention materials and participated in the coaching session, ensuring all participants had access to the resources. School counselors were provided with the protocol to support future implementation.

Reward for participation. At the end of data collection, children and their parents received a €10 gift voucher; teachers received a €15 voucher.

*2.3. Measures*

Socio-demographic information. Basic demographic data were collected from teachers (e.g., gender, age, years of experience) and parents via self-constructed questionnaires adapted from Vandenbroucke et al. (2017). Full details are available in the pre-registration document (Sankalaite et al., 2022; and in Supplementary Materials, Tables S1–S3).

Working memory. WM was assessed using a multi-method, multi-informant approach, necessary for reliably measuring WM's multi-component, dynamic nature (Huizinga et al., 2018).

The primary outcome was informant-reported WM, measured using the adapted 8-item WM subscale of the BRIEF-2 (Gioia et al., 2015; Huizinga & Smidts, 2020). Teachers and parents rated frequency and severity on 10-point scales to detect subtle intervention effects. Internal consistency was high across informants ($\alpha$ = 0.87–0.89). In the experimental group, teachers additionally rated four identified WM-related problematic behaviors via the m-Path application.

The secondary outcome was children's performance WM. Visuospatial WM was measured using a computerized Corsi block tapping task (Corsi, 1972); verbal WM via the WISC-V digit recall (Wechsler, 2014). Given the short pre-post interval, outcome variables included total raw scores and span scores (backward condition) to detect small changes. Given that each item contained two trials (of equal length), a span score of 5 could yield total raw scores ranging from 4 to 8 points.

Teaching strategies. Two measures were employed to assess teachers' strategy use in the classroom as manipulation and fidelity checks. Teachers completed a pre- and post-intervention CLASS-based questionnaire (R. C. Pianta et al., 2008), rating their use of instructional, emotional, and classroom organization strategies ($\alpha$ = 0.75–0.76) on 7-point Likert scales. Additionally, a weekly diary via the m-Path application tracked strategy implementation during the intervention (rated 1–5), including the use of any other-than-trained strategies. Outcome scores reflected the summed target behavior ratings for each of the five trained strategies plus 'other', averaged across completed entries to account for week-to-week variation.

### *2.4. Intervention*

The intervention was developed following the distillation method (Kincade et al., 2020), informed by a systematic literature review (Sankalaite et al., 2021) on TSI interventions targeting EF components and a qualitative study (Sankalaite et al., 2023a) on teachers' strategies for supporting students with WM difficulties. Five key instructional support strategies were identified: feedback, prompting, rules, modeling, and critical thinking, which were specifically selected to be applicable and relevant across all grade levels included in the study (Pollé et al., 2025). Intervention sheets were created for each of these identified strategies.

The focus of the intervention was on instructional strategies provided classroom-wide rather than individual support, ensuring that the strategies were embedded into daily group activities. For example, students were encouraged to generate solutions for their own goals and assist peers in doing so, thereby fostering critical thinking in the classroom.

### *2.5. Statistical Approach*

Data were analyzed using SPSS (Version 28.0). A description of the imputation method is provided in Appendix A.

Since only one child per classroom participated, no multilevel modeling was required. A manipulation check (paired samples *t*-test) assessed increases in teachers' instructional support use. A fidelity check (paired samples *t*-test) evaluated whether trained strategies were applied more frequently than other strategies (m-Path data).

To assess intervention effects, repeated-measures ANOVAs compared pre- and post-intervention scores in informant-reported (primary outcome) and performance (secondary outcome) WM between experimental and control groups. Within the experimental group, paired samples *t*-tests evaluated change in teacher-rated WM-related behaviors. Effect sizes were reported using Cohen's *d* (Cohen, 1988), with thresholds of 0.2 (small), 0.5 (moderate), and 0.8 (large) effects.

## 3. Results

### 3.1. Descriptive Statistics

Independent samples *t*-tests were used to compare experimental and control groups at baseline (see Table S4). No significant differences were found ($\alpha = 0.05$), except for parent-reported WM subscale scores: children in the experimental group showed significantly higher WM-related problems in both frequency ($t(65) = -2.51$, $p = 0.015$, $d = -0.61$, 95% CI [−1.10, −1.12]) and severity ($t(65) = -2.47$, $p = 0.016$, $d = -0.60$, 95% CI [−1.09, −0.11]). While the differences in parental reports are noted, the overall balance across the key variables indicates that potential baseline disparities that might have influenced subsequent intervention effects were minimized, confirming adequate randomization.

### 3.2. Manipulation and Fidelity Checks: Teaching Strategies

To assess changes in teachers' reported strategy use, paired samples *t*-tests were conducted on CLASS-based questionnaire scores. In the experimental group, use of instructional support (the intervention target) increased significantly over time ($t(29) = -2.45$, $p = 0.032$), while emotional support and classroom organization showed no significant changes ($t(29) = -1.89$, $p = 0.068$ and $t(29) = -1.49$, $p = 0.15$, respectively). No significant changes were found in the control group across any domain (instructional support: $t(16) = -1.26$, $p = 0.22$; classroom organization: $t(29) = -0.61$, $p = 0.55$; emotional support: $t(29) = -0.38$, $p = 0.71$), supporting the effectiveness of manipulation. Fidelity was assessed via weekly m-Path diaries in the experimental group. Trained strategies were used significantly more often than untrained ones (*ps* < 0.001).

### 3.3. Primary Outcomes: Informant-Reported Working Memory

To examine intervention effects, repeated-measures ANOVAs compared informant-reported WM scores (frequency and severity) between experimental and control groups across pre- and post-intervention time points.

Teacher ratings showed significant main effects of time and time × condition interactions for both frequency ($F(1,65) = 35.21$, $p < 0.001$, $\eta_p^2 = 0.35$, 95% CI [0.20, 1.00]; interaction: $F(1,65) = 13.18$, $p < 0.001$, $\eta_p^2 = 0.17$, 95% CI [0.05, 1.00]) and severity ($F(1,65) = 32.37$, $p < 0.001$, $\eta_p^2 = 0.33$, 95% CI [0.18, 1.00]; interaction: $F(1,65) = 16.71$, $p < 0.001$, $\eta_p^2 = 0.20$, 95% CI [0.08, 1.00]). Follow-up paired samples *t*-tests confirmed significant decreases in both frequency and severity of WM-related problems in the experimental group ($t(34) = 8.73$, $p < 0.001$ and $t(34) = 6.99$, $p < 0.001$), while no significant changes in the control group were found. The combined results are illustrated in Figure 1, showing the average of combined frequency and severity scores.

Parent ratings similarly indicated significant effects. For frequency, a significant interaction was found ($F(1,65) = 7.49$, $p = 0.008$, $\eta_p^2 = 0.10$, 95% CI [0.02, 1.00]). For severity, both the main effect of time and interaction were significant ($F(1,65) = 6.47$, $p = 0.013$, $\eta_p^2 = 0.09$, 95% CI [0.01, 1.00]; interaction: $F(1,65) = 6.35$, $p = 0.014$, $\eta_p^2 = 0.09$, 95% CI [0.01, 1.00]). Paired samples *t*-tests showed a significant decrease in both frequency and severity of WM-related problematic behavior within the experimental group ($t(34) = 3.52$, $p = 0.001$ and $t(34) = 3.92$, $p < 0.001$), but not in the control group. The combined results are illustrated in Figure 2.

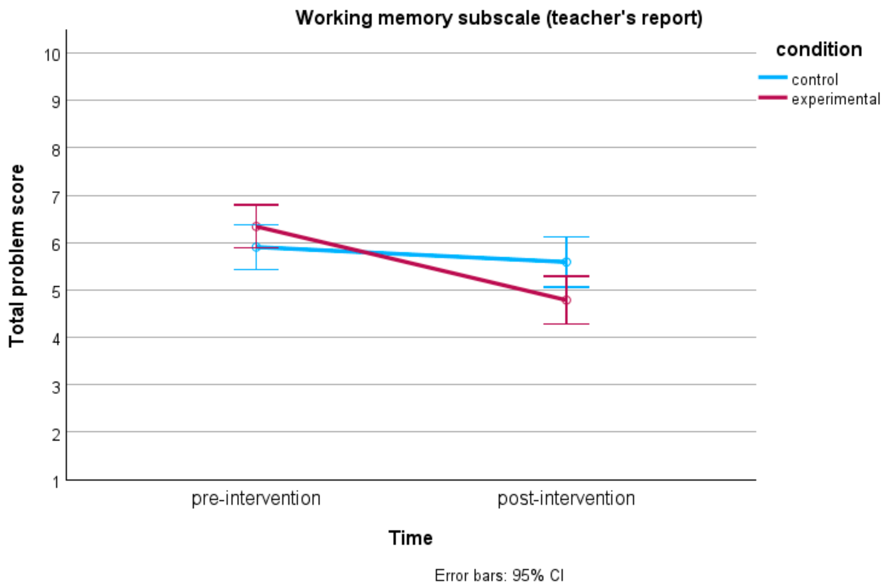


**Figure 1.** Main Effects of Time and Interaction (time × condition) Effects for Total Problem Score of WM Subscale (between group comparison), as reported by the Teachers.

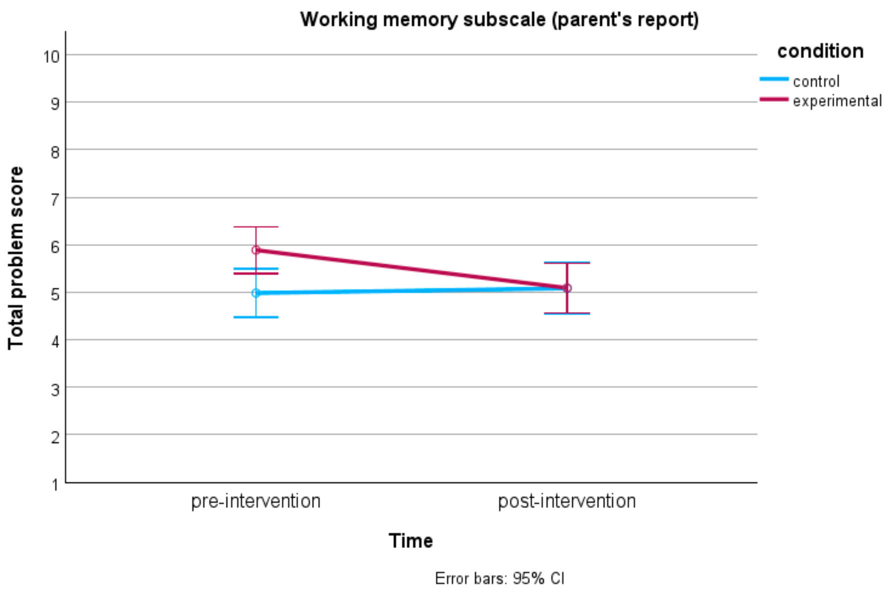


**Figure 2.** Main Effects of Time and Interaction (time × condition) Effects for Total Problem Score of WM Subscale (between group comparison), as reported by the Parents.

Within the experimental group, paired samples *t*-tests confirmed significant pre-post decreases in both frequency and severity across all four WM-related problem behaviors (see Table 2; parent-reported outcomes in Table S5). These results remained significant after applying Holm's (1979) correction for multiple comparisons (Table S6), further supporting the robustness of the intervention effects.

To explore the timing of change, additional analyses compared ratings from pre- to mid-intervention and mid- to post-intervention (Table S7). Significant improvements were observed from pre- to mid-intervention, with no further significant change in the latter interval. Combined scores (averaging frequency and severity) for each behavior are visualized in Figure S2).

**Table 2.** Descriptive Statistics of the Experimental Group at Pre-Intervention and Post-Intervention for Four Problem Behaviors (frequency and severity subscales) and the Results of the Paired Samples *t*-test.

| Experimental Condition | | Pre-Intervention | Post-Intervention | Paired Samples *t*-Test ($n = 35$) |
|---|---|---|---|---|
| Behavior Rating—Teacher | | M (SD) | M (SD) | |
| Problem behavior 1 | Frequency | 8.11 (1.28) | 5.17 (1.71) | $t(34) = 9.68$ *** |
| | Severity | 8.03 (1.52) | 5.29 (1.58) | $t(34) = 10.16$ *** |
| Problem behavior 2 | Frequency | 8.14 (1.44) | 5.00 (1.73) | $t(34) = 9.97$ *** |
| | Severity | 8.51 (1.15) | 5.09 (1.92) | $t(34) = 10.35$ *** |
| Problem behavior 3 | Frequency | 6.97 (1.79) | 3.80 (1.80) | $t(34) = 8.42$ *** |
| | Severity | 7.51 (1.60) | 3.80 (1.83) | $t(34) = 11.10$ *** |
| Problem behavior 4 | Frequency | 7.17 (1.47) | 4.09 (2.16) | $t(34) = 8.29$ *** |
| | Severity | 7.20 (1.62) | 3.89 (2.26) | $t(34) = 8.22$ *** |

*Note:* ***—$p < 0.001$.

To examine predictive effects of initial WM-related behavior, within the experimental group, linear regression analyses were conducted. These analyses examined the predictive relationships between initial WM-related problematic behavior and post-intervention outcomes. The initial problematic behavior data was collected through the mPath application and the outcomes measured included the post-intervention WM-related problematic behavior score, teacher-reported frequency and severity, and parent-reported frequency and severity scores of perceived WM.

The regression model for the post-intervention total problem behavior score was statistically significant, $F(1,33) = 6.42$, $p = 0.016$. The predictor variable (baseline total problem behavior score—data collected through the mPath application) was found to be significant ($\beta = 0.44$, SE = 0.17, $t(33) = 2.53$, $p = 0.016$). The model had an $R^2$ of 0.163, indicating that while it is a significant predictor of the variance in post-intervention scores, other unaccounted factors contribute to 83.7% of the variation in this outcome (see Figure S3). Children's initial WM-related problematic behavior scores were not a significant predictor of either of the parent-reported WM-related outcomes, but were significant for the teacher-reported frequency and severity scores ($F(1,33) = 10.83$, $p = 0.002$) and ($F(1,33) = 10.35$, $p = 0.003$), respectively. The predictor variable (baseline total problem behavior score) for frequency was found to be significant ($\beta = 0.55$, SE = 0.17, $t(33) = 3.22$, $p = 0.003$), with the model accounting for 23.9% of the variance, as shown by the R-squared value of 0.239. Similarly, for severity, the predictor variable was found to be significant ($\beta = 0.53$, SE = 0.16, $t(33) = 3.35$, $p = 0.002$), with the model accounting for 23.1% of the variance, as shown by the R-squared value of 0.231. The combined result is illustrated in Figure S3.

### *3.4. Secondary Outcomes: Performance Working Memory*

In order to examine the intervention effect on performance WM, repeated-measures ANOVAs were used to compare the control and the experimental groups at two time points: pre-intervention and post-intervention.

For visuospatial WM—total span, the results indicated a significant main effect of time ($F(1,65) = 5.11$, $p = 0.027$, $\eta_p^2 = 0.07$, 95% CI [0.00, 1.00]) and interaction effect ($F(1,65) = 5.86$, $p = 0.018$, $\eta_p^2 = 0.08$, 95% CI [0.01, 1.00]), but no significant effects were found for the digit span. Particularly, there was a significant improvement in children's performance in visuospatial WM—total span score ($t(34) = -2.87$, $p = 0.007$) in the experimental group over time, while such an improvement was not seen in the control group. For verbal WM—

both digit and total span, the results indicated no significant main effects. The finding is illustrated in Supplementary Materials (Figure S4).

## 4. Discussion

Previous research has consistently demonstrated a correlational link between TSI and children's WM, providing a compelling foundation for further exploration. However, crucial questions about the malleability of these constructs, as well as the causal nature of this relationship, have remained underexplored. To address this gap, the current TSI pilot study examined the effects of teacher-provided instructional support on primary school children's WM-related problematic behavior and their overall WM capabilities. Current findings provide strong evidence for the intervention's effectiveness—children in the experimental group showed significant and sustained behavioral improvements across all four WM target behaviors. These results support the first hypothesis, namely, that instructional support would lead to pronounced changes in WM-related outcomes. Repeated-measures ANOVAs revealed a significant time × condition interaction, and follow-up analyses confirmed marked decreases in both the frequency and severity of WM-related behaviors in the experimental group, with no corresponding changes in the control group. This pattern indicates that improvements were intervention-driven rather than due to natural developmental trends. Notably, these effects were mirrored in parent reports (despite parents being blind to the intervention condition), highlighting a cross-informant effect and reinforcing the intervention's validity across contexts. The consistency of improvements in both classroom and home environments suggests the effects were not context-specific (Middleton & Baartman, 2013). Given that parents were blind to the condition, these results minimize potential informant bias. Although teachers implemented the intervention and reported on children's problematic behavior, the comparable improvements noted by the parents reduce the likelihood of expectancy effects (Nair, 2022; Roorda et al., 2017; Sandilos et al., 2016). While initial differences in parent-reported perceived WM between groups at baseline could raise concerns about regression to the mean (Galton, 1886), the sustained and multi-informant improvements observed in the experimental group indicate that changes can be attributable to the intervention rather than statistical phenomena. Overall, positive outcomes might be credited to several factors outlined further.

Firstly, the intervention was carefully developed using both empirical and qualitative insights, ensuring that the intervention integrated empirically and theoretically grounded components aimed at enhancing children's WM performance and behavioral outcomes (Kincade et al., 2020). Secondly, a central feature of the intervention was its individualized design, tailored to address specific difficulties and individual needs of children in each classroom. Functional analysis helped teachers identify specific WM challenges and apply targeted instructional support strategies, reinforcing the greater effectiveness of customized interventions over broad, general ones (Connor et al., 2010; Hodges et al., 2018; Jessel et al., 2016). Furthermore, the favorable outcomes of the intervention can also be attributed to the success of implementation (Mullender-Wijnsma et al., 2016; Schultes et al., 2015; Yeung et al., 2015), with teachers in the experimental group increasing instructional (but not emotional or organizational) support, as reflected in the weekly diaries. This was likely facilitated by the intervention's alignment with teachers' existing knowledge and skills, at it focused on modifying the duration, frequency, and timing of support provided, rather than introducing entirely new content (Conroy et al., 2019; Strømme & Furberg, 2015), a process further aided by collaborative coaching (S. R. Holmes et al., 2021; Sobolewski et al., 2021). Moreover, the intervention materials were designed to be engaging, clear, and practical, including illustrative examples, a case study, and a quiz to consolidate teacher understanding and engagement (Rhodes & Lancaster, 2019). Finally, by targeting both antecedents and consequences of behavior, the intervention effectively reduced the frequency and severity of WM-related difficulties, demonstrating the value of a comprehensive classroom management approach (Haley et al., 2010; Kruger et al., 2016; for reviews, see Brosnan & Healy, 2011; Tullis et al., 2012).

Although such findings are encouraging, improvements plateaued after two weeks, indicating limited efficacy over time (Bailey et al., 2020; Walton & Yeager, 2020). It is plausible that while these strategies were effective in initiating behavioral change, they were insufficient to facilitate continued progress beyond weeks 3 and 4 of the intervention. Such plateaus are consistent with evidence that children improve until reaching average performance, after which, further gains are minimal despite continued training (Daelmans et al., 2015; Wetter et al., 2008). Given the potential for further (behavioral) improvement, this pattern highlights the need for improved interventions that can sustain and extend initial progress. In testing the second hypothesis—that children in the experimental group with the most problematic WM-related behavior at baseline would exhibit the largest post-intervention improvements—the results were somewhat unexpected. Contrary to expectations, the initial WM-related problem behavior scores did not significantly predict any of the WM-related outcomes, with the exception of teacher-reported frequency and severity scores on the WM subscale of the BRIEF-2. One explanation may lie in the selection criteria by focusing exclusively on children with poor initial WM performance, the study produced a relatively homogenous participant group in terms of baseline cognitive abilities (Decker & Luedke, 2021; Roberts et al., 2016). This homogeneity may have limited the range of observable improvements, as studies with more heterogeneous samples typically report more pronounced changes in lower-performing participants (Raine et al., 2013). Such differences arise because children with weaker initial performance have more room for development and improvement. Hence, the limited variability in the current sample may have inadvertently restricted the potential for observing varied degrees of improvement, particularly in those with the most severe initial difficulties (Constantinidis & Klingberg, 2016; Peijnenborgh et al., 2015). Alternatively, current findings could suggest that, beyond a certain threshold of difficulty, initial scores are less influential as previously thought (Traut et al., 2021). All children, regardless of their initial ability, appeared to benefit similarly from the intervention (Ben-Itzchak et al., 2014), indicating the broad applicability of the instructional support strategies used (Colmar & Double, 2017; J. L. M. Smith et al., 2016). This suggests that teachers can apply these strategies broadly and expect improvements across different ability levels, though future research with more varied samples are needed to confirm this. Regarding the exploratory hypothesis on children's performance WM, the experimental group showed significant improvements in visuospatial WM total span scores from pre- to post-intervention, with no such changes in the control group. This pattern indicates effects of instructional support rather than natural development. Reported differences between the span score (the length of the series recalled successfully) and total span (the score of correctly recalled series throughout the task) support the idea that total span is more sensitive to subtle changes. The control group showed no significant WM changes, consistent with construct stability over the short four-week interval, reinforcing the conclusion that improvements were intervention-driven (von Bastian & Oberauer, 2013).

### *4.1. Theoretical and Practical Implications, and Future Suggestions*

The current study's exploration of the causal effects of instructional support on children's WM has significant theoretical implications. Demonstrating that instructional support, particularly through scaffolding, causally improves WM (de Wilde et al., 2015; Sankalaite et al., 2021; Vandenbroucke et al., 2018) advances understanding of the TSI-WM dynamic. However, it remains to be seen whether improvements stem from directly strengthening WM or indirectly enhancing performance via a more supportive environment. If the latter is true, where the intervention primarily reduces the cognitive demands on WM rather than directly increasing its capacity, it would suggest that certain environmental modifications can effectively mitigate WM challenges, even without directly improving children's WM. In such cases, factors like increased motivation, enhanced self-efficacy, improved attentional control, and reduced cognitive load may explain such improvements (Brooks et al., 2020; Urhahne & Wijnia, 2023).

In this study, the observed improvements in children's WM-related behavior were notable but plateaued after two weeks. In addition, the intervention's effects did not extend to verbal WM performance. This suggests that instructional support may have optimized the learning environment rather than universally enhancing WM. However, gains in visuospatial WM and evidence of transfer to the home context hint at possible improvements in WM capacity beyond reduced cognitive load. This aligns with (Sankalaite et al., 2023a), who proposed a hierarchy of TSI support. In this framework, emotional support appears least directly related to WM but contributes to an optimal learning environment, while instructional support more directly targets children's WM. The current findings are consistent with this distinction, as improvements were seen not only in perceived WM-related behavior but also, although less pronounced, in children's performance WM. These results carry valuable practical implications, given that WM plays an important role in children's academic performance and social functioning (Cortés Pascual et al., 2019; Spiegel et al., 2021). By showing that tailored instructional support can improve WM in primary school children, the study highlights the importance of integrating TSI and its underlying theoretical mechanisms into teacher training. Such training can deepen understanding of how TSI shapes learning and equip teachers with practical skills to meet diverse student needs.

Implementing this intervention in schools is both viable and scalable. In the current study, teachers received a 1.5 h one-on-one coaching session with a trained professional, but training school counselors to provide ongoing support to all teachers could offer a sustainable, tailored alternative. Since many teachers already use similar strategies (e.g., Elliott et al., 2010), coaching should focus on helping them refine and adapt their practices to classroom contexts rather than introducing entirely new content (Darling-Hammond et al., 2017). Our findings support this, as teachers' instructional support scores were already relatively high before the intervention (see Table S4), indicating substantial existing use of these strategies. Nevertheless, the intervention produced measurable improvements in teachers' application of instructional strategies. In addition, research has increasingly highlighted a close link between the quality of teachers' instructional support and students' EF, including WM. For example, Xu et al. (2024) reported in a recent meta-analysis that higher levels of instructional support are associated with stronger EF outcomes, while Sankalaite et al. (2021) found causal evidence for this relationship in their systematic review. These findings imply that the quality of teachers' instructional support is not only a fundamental component of effective teaching but also a modifiable factor that can directly influence students' executive functioning, including working memory. The difference in the provided instructional support observed between experimental and control groups could indicate that although these strategies form part of standard teacher education, their consistent and tailored application may diminish over time. Therefore, the provided intervention and coaching could, alternatively, function as an effective refresher course within teacher professional development programs (Kraft et al., 2018). Such courses could help teachers periodically update their knowledge, adapt strategies to evolving classroom needs, and sustain systematic application over time (Sims & Fletcher-Wood, 2020). By strengthening teacher-provided instructional support, teachers can continuously support WM-related functioning and, potentially, broader cognitive and academic outcomes.

While the intervention significantly reduced WM-related behavior problems, most children still scored ≥5 after four weeks, suggesting it alone may be insufficient to fully resolve these difficulties. This finding highlights that although the intervention produced positive effect within two weeks, the improvements were not substantial enough to shift children's behavior from a problematic to a non-problematic range. However, it is important to note that microtrials are designed to test mechanisms under controlled conditions rather than achieve full remediation. Future studies should, therefore, examine the impact of other support domains—classroom organization and emotional support—on outcomes such as WM and WM-related behavior, ideally within RCTs that incorporate follow-up assessments to verify the long-term stability of effects. Recent qualitative findings (Sankalaite et al., 2023a) suggest that all support domains can be effective, though their mechanisms differ. Building on this pilot's promising results for instructional support, the current intervention and design offer a strong foundation for testing all support types within the TTI framework (see also Pollé et al., 2025). Additionally, a combined approach using indirect (emotional), semi-direct (organizational), and direct (instructional) strategies may ultimately yield most sustainable improvements. Such an approach is likely to influence not only WM and related behaviors but also motivation, engagement, and confidence, which in turn affect WM-related outcomes. Thus, assessing additional factors and potential moderators is essential to better understand the complex TSI-WM relationship.

### *4.2. Limitations*

Despite promising findings, several limitations warrant consideration. First, the study fell short of its target of 42 triads per condition, despite extensive recruitment efforts, limiting power to detect only medium effects (Baguley, 2004). Second, recruitment may have introduced selection bias, as more motivated or WM-aware teachers might have been more inclined to participate. However, inviting schools rather than individual teachers likely mitigated this risk. Third, the sample lacked cultural and socioeconomic diversity, with most children from Dutch-speaking, upper-middle-class Belgian families, limiting generalizability (Vandenbroucke et al., 2017). Future studies should aim to include more diverse populations to explore whether these relations hold true across different cultural contexts (for a meta-analysis, see Xu et al., 2024). Fourth, because teachers serve both as implementers of the intervention and as raters of their own practices, the data may be subject to bias (Hauser et al., 2018), for instance through over- or underestimation of strategy use or student outcomes. Nevertheless, recent research suggests that teacher self-reports generally align well with observer ratings and can be reliable when collected repeatedly (Cheon et al., 2020; Koziol & Burns, 2015; Wiggs et al., 2023). Given the short duration of the intervention, having an external observer could have unintentionally altered both teacher and student behavior, potentially affecting the results (Liu et al., 2024). Moreover, the main classroom teacher is often best positioned to evaluate a child's behavior due to sustained, comprehensive observations across daily classroom activities. For these reasons, teacher self-reports provide a practical, cost-effective, and ecologically valid method to capture continuous information on strategy use and perceptions of WM that would be difficult to obtain through standardized assessments or external observation alone. Nonetheless, potential self-report biases should be acknowledged. Although blind parent reports showed comparable but smaller effects, future research could include video observations as a more suitable alternative or an added perspective, while taking privacy concerns into account. Fifth, although each teacher rated only one student (removing teacher-level clustering), students were nested within schools, raising the possibility of school-level clustering. Because students within the same school may share contextual factors, outcomes can be correlated (intra-class dependence), which can bias statistical inference if unaccounted for.

To avoid contamination within schools, all teachers in a given school were assigned to the same condition (experimental or control). This design means any school effect is statistically inseparable from the treatment effect. This could be considered a limitation, while noting that random assignment of schools to conditions reduces the likelihood of systematic bias. Lastly, the four-week intervention period, while offering causal insights, may not fully capture its long-term impact since the design was intended to test mechanisms of change rather than produce full intervention effects (Howe et al., 2010). However, the limited effect on performance WM might reflect a 'sleeper effect'—where benefits emerge over time as children internalize and apply new strategies (van Aar et al., 2017). Additionally, the absence of follow-up assessments prevents evaluation of the durability of effects on both informant-reported and performance-based WM. Longitudinal research is needed to assess the persistence and evolution of outcomes over time (Ashworth et al., 2020). Future full-scale studies should, therefore, include a low-burden follow-up to assess maintenance and delayed effects.

### *4.3. Strengths*

By applying a multi-method, multi-informant approach, this study provided a robust and valid assessment of children's WM (Gagne et al., 2021; Gelonch et al., 2016), with all measures showing strong psychometric properties. The only potential restriction was that children's WM was assessed during online administration at their own home. The researchers, therefore, could not always ensure a stimulus-free environment and avoid technical issues (e.g., poor connection, occasional failure to share screen when the child was completing the visuospatial tasks).

Generally, variables assessed with the same method (e.g., two questionnaires) tend to correlate more strongly than those measured differently (e.g., questionnaire vs. task; Podsakoff et al., 2003). Combining behavioral ratings and performance tasks provided a fuller picture, suggesting they tap distinct facets of WM or reflect context-dependent performance (Miyake et al., 2000; Hughes & Graham, 2002).

Moreover, the microtrial design enabled identification of short-term, mechanism-specific effects while balancing experimental precision and ecological validity (Howe et al., 2010). Targeting WM-related behaviors in real classrooms over four weeks allowed for efficient and realistic implementation, supporting early intervention refinement before broader roll-out (Hornstra et al., 2022; Howe et al., 2010). Nonetheless, recent findings highlight that the transition from small-scale trials to large-scale implementation often entails reduced effectiveness and greater contextual complexity (A. C. Smith et al., 2023; Yao et al., 2024). Consequently, although preliminary results appear promising, successful scaling will require careful contextual adaptation alongside further empirical validation. Another strength was blinding parents and children to the condition, reducing expectancy bias and improving internal validity (Page & Persch, 2013). While teachers were aware of their role, independent parent ratings and child task data helped offset bias and added school-home perspectives. Furthermore, the use of two ecologically valid conditions, one experimental and one TAU, enabled meaningful comparison. Because the instructional strategies were minor adaptations of teachers' usual practices, the intervention was both feasible and scalable.

Finally, the intervention was built through triangulation of research, theory, observation tools, and teacher input into a brief, easy-to-implement program. Unlike intensive research-only programs, it shows promise for long-term classroom use, though sustainability remains to be tested. Follow-up is needed to determine whether positive behavioral changes and teacher feedback translate into lasting practice and outcomes (Ashworth et al., 2020; Jaeggi et al., 2013).

Practically, the findings highlight the potential of brief, structured interventions to support cognitive and behavioral development. The gains observed within four weeks suggest that low-cost, scalable strategies can be integrated into everyday classroom routines.

### 4.4. Conclusions

In conclusion, the current study adds valuable insights into the role of teachers and teacher-provided instructional support in positively influencing children's outcomes. Specifically, it demonstrates improvements in informant-reported WM and visuospatial WM performance, as well as noticeable improvements in children's (problematic) behavior in the classroom. These findings highlight the efficacy of a concise, easily implementable, and ecologically valid intervention, as well as its feasibility for integration into regular teaching practices. These promising findings position the approach as a viable way to foster cognitive and behavioral development in primary school children. Future research should build on this foundation with larger microtrials exploring all three support types, long-term effects, and applicability in diverse learning environments. Overall, this study offers practical, scalable strategies for optimizing classroom environments and improving student learning outcomes.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci15101379/s1, Table S1. Socio-Demographic Information of the Participating Teachers; Table S2. Socio-Demographic Information of the Participating Children (as reported by the parent); Table S3. Socio-Demographic Information of the Participating Parents; Table S4. Descriptive Statistics of the Control and the Experimental Groups at Pre-Intervention for Main Variables (questionnaire/task subscales) and the Results of the Independent Samples *t*-test; Table S5. Results of the Pre- to Post-Intervention Changes in Primary Outcome, as reported by the parents; Table S6. Holm's correction for multiple comparisons for the primary outcome—perceived WM; Table S7. Results of the Intermediate Analyses of Changes in the Primary Outcome across Four Weeks; Figure S1. CONSORT Flow Diagram; Figure S2. Total Problem Score (averaged out frequency + severity) for Four Target Behaviors at Pre-, Mid-, and Post-Intervention (within the experimental group); Figure S3. Relationship between Total Score of Pre-Intervention WM-Related Problematic Behavior (collected through the mPath application) and Post-Intervention WM Outcomes (within the experimental group); Figure S4. Main Effect of Time and Interaction Effect for Visuospatial WM Total Span (between group comparison), as performed by the children.

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**Conflicts of Interest:** The authors report there are no competing interests to declare.

## Appendix A Data Imputation

Missing values were imputed in Python (Version 3.12) following confirmation that data were missing completely at random (MCAR), as indicated by Little's MCAR test ($\chi^2(9) = 7.36$, $p = 0.60$; Little, 1988). Missing values were imputed by construct (informant-reported WM and performance WM), with pre- and post-intervention scores combined and analyzed separately by condition. The Iterative Imputer method from scikit-learn (typically using Bayesian Ridge regression) was employed, with multiple imputations performed to enhance robustness (Barnes et al., 2005).

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