



CLASSROOM-BASED WORKING MEMORY TRAINING IN CHILDREN: EVIDENCE FROM A QUASI-EXPERIMENTAL PRIMARY SCHOOL STUDY

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Abstract

This study investigated the effects of a classroom-based Working Memory Training Program on working memory and emotion regulation in second-grade students. A quasi-experimental non-equivalent pretest–posttest control-group design was used. The sample consisted of 49 students from two intact second-grade classrooms in the same public school, with 22 students in the experimental group and 27 in the control group. The experimental group received the Working Memory Training Program for eight weeks, with one session per week, while the control group continued regular classroom instruction. Data were collected using the Working Memory Scale and the Children's Emotion Regulation Scale–Adult Form. Both groups completed pretest and posttest assessments, and the experimental group completed a three-month follow-up assessment to examine the maintenance of gains. Data were analyzed using descriptive statistics, ANCOVA models controlling for pretest scores, bootstrap confidence intervals, and correlation analyses. Results showed that, after controlling for pretest scores, the experimental group had significantly higher posttest scores in verbal working memory, visual working memory, and total working memory. The experimental group also showed significantly higher adjusted posttest scores in anger, excitement, and total emotion regulation, whereas group differences in fear and sadness were not significant. Follow-up findings indicated that gains were generally maintained. Positive correlations were found between working memory and emotion regulation.

Keywords: working memory, emotion regulation, primary education, intervention program, quasi-experimental

INTRODUCTION

Working memory (WM) is a limited-capacity cognitive system that temporarily stores and processes information, enabling individuals to perform complex cognitive tasks such as reasoning, understanding, and learning (Baddeley, 2000; Bruning et al., 2014). Several models have advanced our understanding of WM, including Baddeley and Hitch's (1974) multicomponent model, Cowan's (2005) embedded processes model, and Engle's (2002) attention control framework. These models emphasize WM as both a storage and executive control system critical for adaptive cognition.

Theoretical Framework

Beyond its cognitive functions, WM plays a significant role in emotion regulation (ER), which refers to the processes by which individuals monitor, evaluate, and modify their emotional responses (Gross, 1998). According to Gross's process model, cognitive strategies such as reappraisal require substantial WM resources to maintain emotionally relevant information, reinterpret it, and inhibit dominant responses. Similarly, attentional control theories (Miyake et al., 2000; Kane & Engle, 2002)



suggest that WM supports ER by allocating attention and suppressing irrelevant emotional distractors. Therefore, WM can be conceptualized as a cognitive pathway to ER.

Consistent with this view, meta-analytic evidence shows modest associations between executive functions (including updating, blocking, and replacing) and cognitive reappraisal, suggesting that cognitive control processes are significant components of at least some ER strategies (Toh et al., 2024). More specifically, the ability to update has been proposed as a building block for adaptive ER because it allows individuals to replace dominant negative interpretations with alternative meanings that support reappraisal (Pe et al., 2013).

Empirical research supports these theoretical connections. Individuals with higher working memory capacity are more likely to use adaptive emotion regulation strategies, exhibit lower levels of negative mood, and display greater emotional resilience (Barkus, 2020; Hendricks & Buchanan, 2016; Pe et al., 2013; Xiu et al., 2016). Neuroimaging studies also reveal overlapping neural networks in the prefrontal cortex underlying both working memory and emotion regulation (Schmeichel & Tang, 2015; Schweizer et al., 2019). Conversely, mood states affect working memory performance: negative mood impairs tasks requiring selective attention and updating (Osaka et al., 2013; Hou & Cai, 2022), while positive mood increases planning and flexibility (Phillips et al., 2002).

Developmentally, WM and ER are closely intertwined in childhood; rapid advances in cognitive control coincide with the emergence of self-regulation skills (Malagoli & Usai, 2018; Zaehring et al., 2018). Children with stronger WM exhibit better impulse control, frustration tolerance, and adaptive emotional responses (Kahl et al., 2021). Given that maladaptive ER contributes to psychopathology (Urry & Gross, 2010), clarifying the cognitive foundations of ER in childhood is of both theoretical and practical importance. The relationship between WM and self-regulation is theoretically and empirically supported; however, the main question in intervention studies is whether WM training improves not only performance on target tasks but also broader functioning.

The current literature suggests that WM training yields reliable, direct gains on working memory outcomes (e.g., performance on trained or closely related WM tasks). However, evidence for transfer to broader, nontrained outcomes, such as emotion regulation, is generally small, inconsistent, and context-dependent (Melby-Lervåg & Hulme, 2016; Kassai et al., 2019). Recent child-focused studies have likewise reported improvements in working memory following training (Berger et al., 2025; Hong & Zhou, 2025).

However, there are also arguments suggesting that ER may be a more plausible target for transfer from WM training than many other distal outcomes because ER is a cognitively demanding process requiring the maintenance and updating of mental representations and the suppression of dominant responses (Gross, 1998, 2015; Miyake et al., 2000). Narrative and systematic syntheses focusing on WM training and ER note that gains in ER-related outcomes have been reported in different populations; however, there is considerable heterogeneity in training protocols, outcome measures, and methodological rigor (Barkus, 2020; Papé & Maree, 2023). For example, Barkus's transdiagnostic review summarizes studies reporting improvements in mood and ER-related indicators after standardized WM training and proposes two possible explanations: (a) overlap between cognitive WM, affective WM, and ER systems, and (b) increased cognitive efficiency that may increase available resources under emotional load (Barkus, 2020). Complementing this narrative, a meta-analytic review of emotional working memory training (eWMT) reports improvements in reappraisal and reductions in depressive and anxiety symptoms; however, it highlights the heterogeneity and limited number of available studies (Ou et al., 2026). Taken together, this evidence supports a cautious conclusion: WM-based training may affect ER under some conditions; however, the effects likely depend on the training content (e.g., emotional vs. neutral WM demands), population characteristics, outcome measurement, and implementation context.

The early school years are a period of rapid development in cognitive control and self-regulation, making them theoretically favorable for interventions; however, evidence regarding the transfer of



WM training to ER in children, particularly in school-based settings, is limited and heterogeneous (Papé & Maree, 2023). Theoretically, WM and ER share common cognitive control processes such as executive attention, updating, and inhibition (Engle, 2002; Gross, 1998, 2015; Miyake et al., 2000; Toh et al., 2024); however, meta-analyses show that direct effects of WM training on WM performance are more consistent than transfer effects on broader outcomes (Kassai et al., 2019; Melby-Lervåg & Hulme, 2016). However, executive function training may produce more pronounced far-transfer effects in neurodevelopmental or clinical samples, and WM/inhibition-targeted protocols may reduce mood dysregulation (Bombonato et al., 2024; Groves et al., 2022). These findings underscore the need to test whether WMTP produces transfer to ER in typically developing children in a real school context by evaluating both WM and ER outcomes within the same design (Barkus, 2020; Papé & Maree, 2023).

In summary, three conclusions emerge from the literature most closely related to this study. First, WM and ER are theoretically linked through their shared dependence on cognitive control processes (Engle, 2002; Gross, 2015; Miyake et al., 2000; Toh et al., 2024). Second, WM training can produce reliable, direct improvements in WM outcomes; however, transfer to broader outcomes is not guaranteed and should be addressed as an empirical question (Kassai et al., 2019; Melby-Lervåg & Hulme, 2016). Third, evidence regarding the effects of WM training on ER in children appears limited and mixed, particularly in school-based and classroom-focused contexts; this increases the need for studies that evaluate both WM and ER outcomes together within the same design (Barkus, 2020; Papé & Maree, 2023).

This study evaluated the effects of a classroom-based Working Memory Training Program (WMTP) on both WM and ER in second-grade students. Three research questions guided the study: (1) Do the WMTP and control groups differ in baseline-adjusted posttest verbal, visual, and total WM scores? (2) Do the groups differ in baseline-adjusted posttest ER scores for anger, fear, excitement, sadness, and total ER? (3) Are WM and ER outcomes positively associated? WM outcomes were the direct targets of the program, whereas ER outcomes were considered theoretically plausible secondary transfer outcomes because transfer from WM training is complex and context-sensitive (Barkus, 2020; Melby-Lervåg & Hulme, 2016; Papé & Maree, 2023).

METHOD

Study Design

This study employed a classroom-based quasi-experimental design with a nonequivalent pretest-posttest control-group structure. Two intact second-grade classrooms from the same public primary school participated: one classroom received the WMTP (intervention group) and the other continued with regular classroom instruction as a business-as-usual control group. Because allocation occurred at the classroom level, the design represents a clustered (classroom-based) implementation rather than individual randomization. Such nonequivalent pretest-posttest classroom-based quasi-experimental designs are commonly used in educational field settings when random assignment is not feasible and are particularly relevant for evaluating interventions under real-world constraints (Buluş, 2021; Gopalan et al., 2020; Handley et al., 2018).

The study included three measurement points. At pretest and posttest, both groups completed (a) the Working Memory Scale, which assesses working memory across multiple subdomains in children aged 5–10 years (Ergül et al., 2018), and (b) the Emotion Regulation Scale–Adult Form (Rydell et al., 2003; Turkish adaptation reported by Tatlı-Harmanlı & Güngör-Aytar, 2023). A follow-up (retention/maintenance) assessment was administered three months after posttest and included the same two measures, but it was conducted only with the intervention group to evaluate the maintenance of gains; therefore, follow-up results are interpreted as within-group maintenance evidence rather than as a between-group causal comparison. Detailed information on the measures and scoring procedures is provided below.



Given the nonequivalent-group structure, baseline equivalence could not be assumed. Accordingly, the primary between-group posttest comparisons were planned using baseline-adjusted models, estimating posttest group differences while controlling for pretest scores. Baseline adjustment (e.g., ANCOVA-style adjustment) is widely recommended in pretest–posttest designs because it improves precision and helps account for initial differences between groups (Vickers & Altman, 2001; Van Breukelen, 2006). At the same time, statistical adjustment cannot fully eliminate selection bias if intact groups differ systematically on unmeasured factors; therefore, causal interpretations should remain cautious in quasi-experimental contexts (Gopalan et al., 2020; Shadish et al., 2002).

Participants

Participants were second-grade students from two intact classrooms in a public primary school in Central Anatolia, Türkiye (2022–2023 academic year). The study used a feasibility-based sample determined by the availability of these classrooms. One classroom was designated as the experimental group (Working Memory Training Program; WMTP) and the other as the business-as-usual control group, reflecting implementation under natural school conditions.

Initially, 52 children were enrolled (experimental $n = 23$, control $n = 29$). Three students discontinued participation (experimental: 1; control: 2) and were excluded from all analyses, including baseline, yielding a final analytic sample of 49 children (experimental $n = 22$, control $n = 27$). No a priori power analysis was conducted because the sample size was constrained by classroom availability; results are therefore interpreted using effect sizes and confidence intervals in addition to p -values.

Eligibility required classroom enrollment, parental consent, and child assent. Both groups completed pretest and posttest assessments; a follow-up assessment was administered only to the experimental group and treated as within-group maintenance evidence. Make-up sessions were offered to support intervention attendance.

Intervention: Working Memory Training Program (WMTP)

WMTP is a classroom-based, game-mediated intervention developed by the authors (the research team) for second-grade students. The program was designed to promote active participation, accommodate individual differences, and support collaborative learning through child-centered instructional practices aligned with progressive education principles. The WMTP is grounded in Information Processing Theory and the multicomponent working memory model (Baddeley & Hitch, 1974; Baddeley, 2000). Accordingly, the program targets working memory components through four instructional modules: visuospatial sketchpad, phonological loop, episodic buffer, and central executive.

The program was developed using the Taba–Tyler curriculum development model, beginning with a needs analysis and proceeding through specification of goals and objectives, selection and organization of content, design of learning experiences, and iterative refinement. The needs analysis combined an analytical review of relevant programs and research with a democratic component that included interviews with a child development expert, a program development expert, and three classroom teachers. Stakeholders consistently emphasized that, for second-grade students, working-memory activities should be short, concrete, highly engaging, game-based, and supported by visual and multisensory elements; experts also underscored the importance of structured repetition and flexibility to accommodate individual differences. Accordingly, WMTP was structured using a modular programming approach, and within key modules (particularly the visuospatial and phonological components) learning experiences were arranged in a spiral progression, revisiting core skills while gradually increasing complexity.

Importantly, the WMTP did not include explicit emotion regulation instruction. Instead, it was designed to strengthen working-memory processes with the hypothesis that improved cognitive control would indirectly support children’s emotion regulation capacities.

WMTP consisted of 21 developmentally appropriate activities delivered across eight weekly sessions. Each session typically included two to three consecutive activities and lasted approximately one to



two class periods, depending on classroom pacing. The session plan (see Table 1) mapped activities and strategies to the targeted working memory components. Across sessions, children practiced strategies embedded in classroom tasks, including rehearsal/inner repetition, grouping/chunking, segmentation, storytelling/narrative elaboration, and mnemonic supports. Activities were implemented through educational games, question–answer interactions, and, when appropriate, computer-assisted tasks, with an emphasis on active, guided practice rather than passive instruction. Table 1 summarizes the eight-session structure of the WMTP, including the targeted working memory components, strategies, and activities.

Table 1. Structure of the WMTP

Session	Working Memory Component	Strategy	Activities
1	Working Memory (Introduction)	—	Treasure Hunt – Getting to Know Game; Touch the Number I Say
2	Visuospatial Domain	Rehearsal (inner repetition); Chunking (grouping)	Remembering What I Said; Shopping Basket; Find What’s Missing
3	Phonological Loop	Chunking (grouping)	I Went to the Market Game; Pumpkin Game; Listen, Grasp, Draw
4	Episodic Buffer	Storytelling; Chunking (grouping)	Story Cubes; Waiter Game
5	Visuospatial Domain	Elaboration / Meaning-making	Cup Game; Fast Seer Wins
6	Phonological Loop	Rehearsal (inner repetition)	Catch the Rhythm; My Teacher Says That; Camel–Gücüye
7	Visuospatial Domain	Mnemonics	Touch the Color I Say; Fast Colors Game; Encoding
8	Central Executive	Elaboration / Linking (integration)	Reverse Cup Game; LEGO Construction; Divided Attention

To strengthen the validity and applicability of the program's content, it was reviewed by five experts in child development and education, and a pilot implementation was conducted with five second-grade students. The feedback was used to improve the activity instructions, pacing, and materials.

The program was delivered by the researcher, who had completed formal training and certification for administering the Working Memory Scale. Fidelity was supported through standardized session plans and instructions, monitoring of attendance and dose, and make-up opportunities for missed sessions. The control group did not receive the WMTP during the study; after completion of data collection, the training materials were provided to the control-group teacher, but subsequent implementation was not monitored as part of this study.

Measures

Working memory assessment

Working memory was assessed with the Working Memory Scale (WMS) developed for children aged 5–10 years (Ergül et al., 2018). The WMS comprises four domains and nine subtests: verbal short-term memory (Digit Recall, Word Recall, Nonword Recall), visual short-term memory (Dot/Pattern Matrix, Block Recall), verbal working memory (Backward Digit Recall, First Word Recall), and visual working memory (Odd-One-Out, Spatial Discrimination/Span). Subtests are administered in sequences that increase in length, typically with two trials per level; administration proceeds as long as the child meets the continuation rule and is discontinued when the stopping criterion is reached (i.e., failure on both trials at a given level). Each correctly recalled sequence is scored 1, whereas an incorrect sequence is scored 0. For the present study, subtests were aggregated into modality-based composites: Verbal Memory (sum of all verbal short-term and verbal working memory subtests) and Visual Memory (sum of all visual short-term and visual working memory subtests). A total score was computed as the sum of the Verbal and Visual composites and was used as the primary overall index in analyses. In the present study, the total WMS score demonstrated high internal consistency (Cronbach’s $\alpha = .91$).

**Emotion regulation measure (adult form)**

Emotion regulation was measured using the adult-report version of the Emotion Regulation Scale for Children (Rydell et al., 2003; Turkish adaptation by Tatlı-Harmancı & Güngör-Aytar, 2023). The ERS-A includes 40 items covering four emotion domains (anger, fear, excitement/enthusiasm, and sadness) and yields scores reflecting emotion regulation (and, separately, emotion intensity). Parents rated each item on a 5-point Likert scale (1–5); item responses were summed according to the scoring guidelines (including reverse-coded items, where applicable) to compute a total emotion regulation score, with higher scores indicating better overall regulation as defined by the scale. In line with the study aims, analyses used only the total emotion regulation score; the emotion intensity dimension was not analyzed because it was not targeted by the intervention, thereby maintaining a parsimonious set of outcomes. Internal consistency for the ERS-A total score in the present sample was acceptable (Cronbach's $\alpha = .82$).

Demographics

Demographic and background information was obtained via a Personal Information Form. Variables included child age and gender, maternal and paternal education levels, number of siblings, birth order, and preschool education attendance. These data were used to describe the sample and, where relevant, in adjusted analyses to account for potential confounding influences in group comparisons and association tests.

Procedure

Following ethical approval from the Gazi University Scientific Publication and Ethics Committee (No. E.585142; 09/02/2023) and official implementation permission from the Ministry of National Education (No. E.74258403; 12/04/2023), the study was conducted in a public primary school located in a central district in Central Anatolia, Türkiye. Two intact second-grade classrooms from the same school participated. Because individual randomization was not feasible in the natural school context, group allocation occurred at the classroom level: One classroom was designated as the WMTP intervention group and the other served as a business-as-usual control group continuing routine instruction without any additional cognitive training activities or WMTP materials.

After obtaining written parental informed consent and child assent, baseline assessments were administered. Children in both groups completed the WMS individually in a quiet room at school (Support Education Room) using standardized instructions, with each assessment lasting approximately 20–30 minutes. In the same week as the child pretest assessments, parents completed the Emotion Regulation Scale–Adult Form face-to-face with the researcher at school.

The intervention began in the first week following the pretest. The WMTP was delivered over eight consecutive weeks, with one session per week during the school day (typically after lunch) in the intervention classroom. Sessions followed a standardized structure (brief warm-up/attention-focusing activity, core working memory tasks, brief reflection and strategy emphasis, and closure) and were delivered by the first author. Attendance was monitored throughout the program, and make-up sessions were offered when needed to minimize missed exposure. The control group continued with regular classroom activities during this period.

Immediately after the final WMTP session (i.e., in the last week of the intervention period), posttest assessments were administered. Posttest procedures mirrored baseline procedures: children were assessed individually in the same setting and under the same standardized conditions. During the same posttest week, parents again completed the Emotion Regulation Scale–Adult Form face-to-face with the researcher.

To examine maintenance of gains, a follow-up assessment was conducted approximately three months after the end of the intervention for the intervention group only. The follow-up was framed as within-group maintenance/retention evidence rather than a between-group causal comparison because the control group did not complete follow-up assessments. Follow-up procedures replicated the earlier assessment conditions: children were assessed individually in the same quiet room using the same



measures and standardized instructions, and parents completed the Emotion Regulation Scale–Adult Form face-to-face with the researcher during the same follow-up week.

Initially, 52 children were enrolled (intervention $n=23$, control $n=29$). Three children discontinued participation (intervention: 1; control: 2) and were excluded from analyses because they did not complete the measurement sequence, resulting in a final analytic sample of 49 children (intervention $n=22$, control $n=27$).

Data Analysis

All analyses were conducted using IBM SPSS Statistics (Version 26). Prior to hypothesis testing, data were screened for accuracy, missingness, outliers, and assumption violations. There were no missing data for the primary study variables; therefore, analyses were conducted using complete cases. Descriptive statistics (means, standard deviations, and ranges) were computed for each outcome by group and measurement occasion (pretest, posttest, and, when available, follow-up). Normality was evaluated using Shapiro–Wilk tests and inspection of skewness and kurtosis values and Q–Q plots. Homogeneity of variances was assessed with Levene’s test. The significance level was set at $\alpha = .05$ (two-tailed). Along with p-values, effect sizes and confidence intervals were reported to support interpretation.

Because participants were assigned at the classroom level (two intact classes) and baseline equivalence could not be assumed, posttest program effects were estimated using analysis of covariance (ANCOVA). Separate ANCOVA models were fitted for each working memory outcome (verbal, visual, and total) and each emotion regulation outcome (anger, fear, excitement, sadness, and total). In each model, the corresponding posttest score served as the dependent variable, group (WMTP vs. business-as-usual control) was the fixed factor, and the corresponding pretest score was entered as a covariate to adjust for baseline differences. Baseline-adjusted posttest group means (estimated marginal means) and adjusted mean differences (WMTP – control) were reported. Because group assignment occurred at the classroom level and only two intact classrooms were included, classroom-level influences could not be modeled separately from intervention effects. Therefore, all student-level analyses should be interpreted with caution, particularly with regard to causal inference.

Given the quasi-experimental design and the possibility of heterogeneity of variances in some outcomes, bootstrap bias-corrected and accelerated (BCa) 95% confidence intervals for adjusted mean differences were computed as a robustness check using 2,000 resamples. Partial eta squared (η^2) was reported for the omnibus group effect in each ANCOVA.

Follow-up assessments were administered only to the WMTP group; therefore, follow-up results were not used for between-group causal inference. Maintenance of gains within the WMTP group was examined descriptively (pretest–posttest–follow-up means and standard deviations) and, where appropriate, with repeated-measures analyses across the three time points (pretest, posttest, follow-up). These follow-up findings were interpreted as evidence of maintenance/retention within the intervention group and were reported in the Supplementary Material to keep the main Results focused on primary between-group estimates.

Bivariate associations between working memory indices (verbal, visual, total) and emotion regulation outcomes (subscales and total) were examined using Pearson product–moment correlations (two-tailed). To evaluate whether the association between total working memory and total emotion regulation remained after accounting for relevant child and family characteristics, partial correlations were computed while controlling for child age, number of siblings, birth order, child gender, mother’s education, father’s education, and preschool education attendance. Correlation coefficients (r), corresponding p-values, and degrees of freedom were reported.

RESULTS

This section presents the quantitative findings regarding the effectiveness of WMTP. The results are organized to examine (i) the program’s effects on working memory performance (verbal, visual, and



total); (ii) emotion regulation indicators; and (iii) the associations between working memory and emotion regulation. Descriptive statistics are reported first, followed by inferential analyses aligned with the study research questions. When appropriate, effect sizes and confidence intervals are provided to strengthen the reporting.

Effect of WMTP on Working Memory

This subsection examines the effect of WMTP on working memory performance. First, pretest and posttest means for the experimental and control groups, along with the follow-up assessment administered to the experimental group, are summarized. Next, between-group differences in posttest working memory outcomes are tested using ANCOVA while controlling for pretest scores. Because the follow-up assessment was collected only in the experimental group, follow-up findings are interpreted descriptively as an indicator of maintenance rather than as a between-group program effect.

Table 2. Pretest, posttest, and follow-up means (SD) for working memory in the experimental and control groups

Outcome	Group	Pre-test Mean (SD)	Post-test Mean (SD)	Follow-up Mean (SD)*
Verbal Memory	Experimental	12.32 (3.97)	16.50 (4.73)	17.27 (5.61)
	Control	16.04 (5.03)	17.59 (5.81)	—
Visual Memory	Experimental	5.68 (4.13)	8.59 (4.55)	9.23 (4.14)
	Control	7.30 (3.58)	8.30 (3.52)	—
Total WM	Experimental	18.00 (7.30)	25.09 (8.48)	26.50 (9.00)
	Control	23.33 (7.20)	25.74 (8.12)	—

*Follow-up was administered only to the experimental group.

Descriptive results indicate that the experimental group showed increases from pretest to posttest in verbal memory, visual memory, and total working memory, and that these gains were generally maintained at follow-up. However, because the control group had higher pretest means on some sub-dimensions (particularly verbal memory and total working memory), the groups were not fully equivalent at baseline. Therefore, evaluating program effects based on between-group posttest differences while controlling for pretest scores was considered more appropriate.

At follow-up, the experimental group's scores generally showed a stable or increasing trend; detailed follow-up results are provided in the Supplementary Material (see Supplementary Table S1).

Following the descriptive findings, the effect of WMTP on posttest working memory outcomes was examined using ANCOVA with pretest scores as covariates. For each sub-dimension, we report the group effect (F , p , and η^2), baseline-adjusted (estimated marginal) posttest means, and bootstrap BCa 95% confidence intervals for the adjusted mean differences (Table 3).

Table 3. ANCOVA results for posttest working memory outcomes (adjusted for pretest scores) and Bootstrap BCa CI

Outcome	Levene p	Group effect (df)	F	p	η^2	Adjusted Posttest Mean (SE) Exp	Adjusted Posttest Mean (SE) Ctrl	Adj. Mean Diff (Exp–Ctrl) BCa 95% CI
Verbal Memory	.327	Group (1,46)	14.793	<.001	.243	18.653 (.525)	15.838 (.470)	2.815 ** [1.410, 4.133]
Visual Memory	.039	Group (1,46)	6.311	.016	.121	9.359 (.494)	7.671 (.445)	1.688 * [.314, 3.136]
Total	.381	Group (1,46)	21.676	<.001	.320	28.154 (.761)	23.245 (.682)	4.909 ** [2.806, 7.058]

Note. η^2 = partial eta squared. Adjusted means are estimated marginal means from ANCOVA evaluated at the sample mean of the covariate. The 95% confidence intervals for adjusted mean differences are bootstrap BCa intervals based on 2,000 resamples. * $p < .05$. ** $p < .01$.



After controlling for pretest scores, the experimental group scored significantly higher than the control group on posttest verbal working memory, visual working memory, and total working memory. Effect sizes were $\eta^2 = .243$ for verbal working memory, $\eta^2 = .121$ for visual working memory, and $\eta^2 = .320$ for total working memory, with the largest effect observed for total working memory. In addition, the bootstrap BCa 95% confidence intervals for the adjusted mean differences did not include zero, supporting the direction and consistency of the between-group effects.

Effect of WMTP on Emotion Regulation

In this section, the effects of WMTP on children's emotion regulation are reported. First, descriptive statistics (pretest, posttest, and follow-up means and standard deviations) are presented for the experimental and control groups. Next, to evaluate the program effect on posttest outcomes while accounting for baseline differences, posttest emotion regulation scores were compared between groups using ANCOVA with pretest scores entered as a covariate. Along with the omnibus group effects (F, p, and partial eta squared), baseline-adjusted (estimated marginal) posttest means and bootstrap BCa 95% confidence intervals for the adjusted mean differences are reported. Follow-up (maintenance) data were collected only in the experimental group and are therefore reported in the Supplementary Material as descriptive information rather than as a between-group test. Table 4 presents these descriptive statistics.

Table 4. Pretest, posttest, and follow-up means (SD) for emotion regulation in the experimental and control groups

Subscale	Group	Pretest Mean (SD)	Posttest Mean (SD)	Follow-up Mean (SD)*
Anger	Experimental	16.73 (3.99)	19.77 (4.18)	19.41 (3.82)
	Control	23.30 (4.79)	23.81 (1.57)	—
Fear	Experimental	17.82 (4.50)	19.77 (3.90)	19.68 (3.80)
	Control	24.19 (3.55)	24.19 (2.04)	—
Excitement	Experimental	17.86 (4.38)	20.55 (4.21)	20.55 (4.21)
	Control	23.59 (3.57)	22.48 (2.64)	—
Sadness	Experimental	18.45 (3.16)	19.45 (4.21)	19.36 (3.42)
	Control	23.22 (4.60)	23.04 (2.82)	—
Total	Experimental	70.86 (13.58)	79.55 (14.40)	79.00 (13.29)
	Control	94.30 (4.78)	93.52 (5.27)	—

*The follow-up assessment was administered only to the experimental group.

As shown in Table 4, the experimental group increased from pretest to posttest across all subscales and the total score. In the control group, the pattern was less consistent: anger scores increased slightly, fear scores remained unchanged, whereas excitement, sadness, and total emotion regulation scores decreased from pretest to posttest. At follow-up, scores in the experimental group remained close to their posttest levels across all outcomes, suggesting maintenance of the observed posttest gains.

Because the groups differed at baseline on emotion regulation scores (Table 4), posttest outcomes were compared using ANCOVA with corresponding pretest scores entered as covariates. For each outcome, we report the group effect (F, p, η^2), baseline-adjusted (estimated marginal) posttest means, and bootstrap BCa 95% confidence intervals for the adjusted mean differences (Exp – Ctrl) (Table 5).

Table 5. Baseline-adjusted posttest comparisons for Emotion Regulation: ANCOVA and Bootstrap BCa CIs to CIs

Subscale	Levene p	Group effect F(1,46)	p	η^2	Adjusted Posttest Mean (SE) Exp	Adjusted Posttest Mean (SE) Ctrl	Adj. Mean Diff (Exp–Ctrl) BCa 95% CI
Anger	.046	6.12	.017*	.117	22.31 (.69)	20.92 (.62)	1.39 [.25, 2.74]
Fear	.388	3.04	.088	.062	22.21 (.68)	21.18 (.60)	1.03 [–.18, 2.31]



Table 5 (Continued). Baseline-adjusted posttest comparisons for Emotion Regulation: ANCOVA and Bootstrap BCa CIs to CIs

Subscale	Levene p	Group effect F _(1,46)	p	η^2	Adjusted Posttest Mean (SE) Exp	Adjusted Posttest Mean (SE) Ctrl	Adj. Mean Diff (Exp–Ctrl) BCa 95% CI
Excitement	.382	5.27	.026*	.103	22.97 (.77)	21.39 (.69)	1.58 [.19, 3.06]
Sadness	.229	1.41	.241	.030	21.23 (.75)	20.47 (.68)	.76 [–.59, 2.20]
Total	.110	5.84	.020*	.113	88.12 (2.21)	83.94 (2.00)	4.18 [–.76, 7.96]

Note. η^2 = partial eta squared. Adjusted means are estimated marginal means from ANCOVA evaluated at the sample mean of the covariate. Confidence intervals for adjusted mean differences (Exp–Ctrl) are bootstrap BCa 95% CIs based on 2,000 resamples.

After controlling for pretest scores, significant group differences favoring the experimental group were found for anger, $F_{(1, 46)} = 6.12$, $p = .017$, $\eta^2 = .117$; excitement, $F_{(1, 46)} = 5.27$, $p = .026$, $\eta^2 = .103$; and total emotion regulation, $F_{(1, 46)} = 5.84$, $p = .020$, $\eta^2 = .113$. The baseline-adjusted posttest mean was higher in the experimental group than in the control group for anger (22.31 vs. 20.92; adjusted mean difference = 1.39, BCa 95% CI [0.25, 2.74]), excitement (22.97 vs. 21.39; adjusted mean difference = 1.58, BCa 95% CI [0.19, 3.06]), and total emotion regulation (88.12 vs. 83.94; adjusted mean difference = 4.18, BCa 95% CI [–.76, 7.96]). In each case, the bootstrap confidence interval excluded zero, consistent with the ANCOVA results.

In contrast, the adjusted between-group differences were not statistically significant for fear, $F_{(1, 46)} = 3.04$, $p = .088$, $\eta^2 = .062$, or sadness, $F_{(1, 46)} = 1.41$, $p = .241$, $\eta^2 = .030$. Although the adjusted posttest means were numerically higher in the experimental group for both fear (22.21 vs. 21.18) and sadness (21.23 vs. 20.47), the corresponding bootstrap BCa 95% confidence intervals included zero (fear: adjusted mean difference = 1.03, 95% CI [–.18, 2.31]; sadness: adjusted mean difference = .76, 95% CI [–.59, 2.20]), providing no statistically significant evidence of between-group differences for these outcomes.

Levene’s test suggested potential heterogeneity of variances for the anger subscale ($p = .046$), whereas it was not significant for the remaining outcomes (Table 5). Accordingly, the bootstrap BCa confidence intervals are emphasized as a robustness check for the adjusted mean differences.

Relationship Between Working Memory and Emotion Regulation

This section examines the associations between working memory (verbal, visual, and total) and emotion regulation (anger, fear, excitement, sadness, and total). Pearson product–moment correlation coefficients (two-tailed) were computed to evaluate bivariate relationships. In addition, partial correlations were conducted for the association between total working memory and total emotion regulation, controlling for child age, number of siblings, birth order, child gender, mother’s education, father’s education, and preschool education attendance. Table 6 summarizes these bivariate and partial correlations.

Table 6. Pearson correlations between working memory and emotion regulation (total) and partial correlation for total scores

Working memory	Anger	Fear	Excitement	Sadness	Emotion Regulation (Total)	Partial r (Total ER)*
Verbal Memory	.27	.37**	.35*	.39**	.37**	.26
Visual Memory	.24	.32*	.34*	.36*	.34*	.25
Total WM	.29*	.40**	.39**	.43**	.41**	.31*

Note. N = 49. Values are Pearson correlation coefficients (two-tailed). * $p < .05$. ** $p < .01$.

*Partial correlations are reported for the association between each working memory index and total emotion regulation, controlling for age, number of siblings, birth order, gender, mother’s education, father’s education, and preschool education attendance (df = 40).

As shown in Table 6, verbal working memory was positively correlated with fear ($r = .37$, $p < .01$), excitement ($r = .35$, $p < .05$), sadness ($r = .39$, $p < .01$), and total emotion regulation ($r = .37$, $p < .01$), whereas its correlation with anger was not significant ($r = .27$, $p = .058$). Visual working memory



showed significant positive correlations with fear ($r = .32, p < .05$), excitement ($r = .34, p < .05$), sadness ($r = .36, p < .05$), and total emotion regulation ($r = .34, p < .05$), but was not significantly related to anger ($r = .24, p = .104$). Total working memory was positively correlated with anger ($r = .29, p < .05$), fear ($r = .40, p < .01$), excitement ($r = .39, p < .01$), sadness ($r = .43, p < .01$), and total emotion regulation ($r = .41, p < .01$). Finally, the association between each working memory index and total emotion regulation remained positive after controlling for covariates (verbal WM: partial $r = .26, p = .099$; visual WM: partial $r = .25, p = .107$; total WM: partial $r = .31, p < .05$; $df = 40$), indicating that only the total working memory–total emotion regulation association remained statistically significant after covariate adjustment.

DISCUSSION, CONCLUSION, and RECOMMENDATIONS

This study investigated whether a WMTTP implemented in a classroom setting was associated with gains in WM and ER in second-grade children and whether these areas were interrelated. Overall, the findings pointed to a clearer and more pronounced pattern for the primary cognitive goals of the intervention than for the broader socio-emotional outcomes. After accounting for baseline differences, the intervention group demonstrated higher posttest scores than the control group in verbal, visual, and total working memory, and follow-up scores for the experimental group showed that these gains were maintained over time. Emotion regulation outcomes were also generally positive, but these should be interpreted more cautiously as potential transfer effects rather than direct effects of a program that explicitly targets emotional processes.

The clearest effects in the present study were observed for working memory outcomes, which is consistent with the literature indicating that working memory training tends to produce its most reliable benefits on targeted or near-transfer measures. Bharadwaj et al. (2022) demonstrated in their meta-analysis that working memory training yielded significant post-intervention improvements in verbal and visuospatial working memory in school-age children, with only limited evidence for more distal transfer. Likewise, Vernucci et al. (2023) reported that process-based training improved working memory performance in typically developing school-age children, while also noting that broader transfer effects were less uniform. Extending this pattern to ecologically valid school settings, Berger et al. (2025) found substantial immediate and lasting gains in children's working memory capacity following a randomized educational intervention. Hong and Zhou (2025) further showed that computerized working memory training can enhance children's working memory capacity, although these gains are shaped by the characteristics of the training task itself. Against this background, the present findings, showing clearer improvements in verbal, visual, and total working memory than in more distal outcomes, fit well with the broader conclusion that working memory training most robustly affects the cognitive functions it directly engages.

The effects of the intervention were not equally strong across all working memory outcomes, and this pattern is consistent with previous research. In the present study, gains were more pronounced for total and verbal working memory than for visual working memory. Similar variation has been reported in the literature. For example, Bharadwaj et al. (2022) found post-intervention improvements in both verbal and visuospatial working memory, but only verbal working memory showed evidence of maintenance at follow-up, suggesting that some working memory domains may be more responsive or more stable over time than others. Likewise, Vernucci et al. (2023) concluded that process-based training can improve untrained working memory performance in typically developing school-age children, although the size of these gains may differ across outcomes. Dunning et al. (2013) and Henry et al. (2014) reported a similar pattern, with clearer gains on working memory measures than on broader cognitive or academic outcomes. Taken together, these studies suggest that the stronger gains observed here in verbal and total working memory, relative to visual working memory, are not unusual. Rather, they likely reflect differences in how closely the training activities matched the outcome measures, as well as variation in the cognitive demands and developmental sensitivity of different working memory components.



The emotion regulation findings in the present study are best interpreted as promising but secondary transfer effects rather than direct outcomes of the intervention. This interpretation is consistent with Barkus's (2020) review, which showed that working memory training can support several emotion-related outcomes, although these effects are typically less consistent than gains on targeted cognitive measures. Similarly, Tzuriel et al. (2024) found that non-computerized working memory training in typically developing preschool children improved not only some working memory outcomes but also some self-regulation measures, whereas transfer did not extend uniformly across all domains. Likewise, Zhao and Zhang (2024) reported that working memory training in children with ADHD improved adaptive cognitive emotion-regulation strategies and reduced maladaptive strategies, with effects maintained at follow-up. In the same vein, Bombonato et al. (2024) concluded that executive-function training can yield far-transfer effects in children but also emphasized substantial heterogeneity across studies. Taken together, this literature suggests that improvements in emotion regulation following working memory training are theoretically plausible and empirically supported under some conditions, but they should still be interpreted cautiously because they are more variable and context-sensitive than gains on targeted working memory outcomes.

A plausible explanation for these transfer effects is that working memory and emotion regulation rely on partially overlapping self-regulatory processes, especially controlled attention, goal maintenance, and the inhibition of less adaptive responses. Wolfe and Bell (2007) provided early developmental evidence that working memory is closely linked to attentional and regulatory processes, while Raver and Blair (2016) argued that children's adaptation depends on an integrated system of cognitive, emotional, and behavioral regulation. Similarly, Zelazo and Carlson (2012) emphasized that both "cool" and "hot" executive functions depend on top-down control, even when expressed in affectively different contexts. More recent studies support the functional significance of this overlap. Groves et al. (2020, 2022) showed that poorer working memory is associated with greater emotion dysregulation, whereas better-developed working memory predicts better emotion regulation. Experimental findings also point in the same direction: Xie et al. (2021) and Li et al. (2020) reported that executive-function training improved both cognitive control and emotion-related functioning in young children. Within this framework, the present pattern, showing clearer gains in anger, excitement, and total emotion regulation, but not in fear or sadness, may suggest that the WMTP primarily supported specific aspects of emotion regulation rather than producing uniform improvements across emotional domains. Accordingly, the nonsignificant findings for fear and sadness should not be taken as contradicting the overall findings, but rather as indicating that transfer to emotion regulation may be selective, with some emotional domains appearing more sensitive than others to improvements in children's underlying cognitive-control systems.

The correlational findings further support the view that working memory and emotion regulation are developmentally linked through shared self-regulatory processes. In the present study, verbal WM was positively associated with fear, excitement, sadness, and total ER, whereas its association with anger was not statistically significant. Visual WM was positively associated with fear, excitement, sadness, and total ER, but not with anger. Total WM, by contrast, was positively associated with all ER outcomes, and its relation with total ER remained significant even after controlling for age, number of siblings, birth order, gender, parental education, and preschool education attendance. Wolfe and Bell (2007) showed that early attentional and regulatory processes are closely tied to later working memory performance, while Raver and Blair (2016) conceptualized self-regulation as an integrated system in which cognitive, emotional, and behavioral control processes jointly support children's adaptation. Similarly, Zelazo and Carlson (2012) argued that both cool and hot executive functions rely on top-down control, making it plausible that stronger working memory would be associated with better emotion regulation. More direct support comes from Groves et al. (2020, 2022), who reported that poorer working memory was linked to greater emotion dysregulation, whereas stronger working memory predicted better emotional functioning. Taken together, the present findings suggest that the WM-ER association is most meaningfully understood at the level of general



regulatory capacity: children with stronger working memory may be better able to maintain goals, direct attention, and inhibit less adaptive responses when managing emotional demands.

A key strength of this study is that it contributes at both theoretical and contextual levels. First, WMTP demonstrated its most pronounced effects on its targeted outcomes: verbal, visual, and total working memory, reinforcing confidence in the specificity and structural fit of the intervention. Second, the study contributes not only by evaluating intervention-related outcomes but also by examining the association between working memory and emotion regulation, thus offering theoretically relevant insight into how cognitive and emotional self-regulation may be connected. Third, the emotion regulation findings should be interpreted cautiously, but the presence of positive patterns across various indicators of emotion regulation provides preliminary evidence that the effects of school-based working memory training may extend beyond narrowly defined cognitive performance. Another strength is the inclusion of follow-up data for the intervention group, allowing for at least an initial examination of sustainability rather than limiting interpretation to immediate posttest effects. Finally, the implementation of the program in a real school setting enhances the practical significance of the findings by demonstrating that a structured, developmentally appropriate working memory intervention can be delivered under ordinary educational conditions. Taken together, these features strengthen the study's contribution by positioning it not merely as an educational trial but as a contextually grounded and theoretically informed investigation into how a school-based cognitive intervention can support children's broader self-regulatory functioning.

Limitations

These findings should be evaluated in light of several methodological limitations, while also considering the strengths of the study. First, the study used a quasi-experimental design with existing classrooms in a natural school setting. ANCOVA adjusted for observed pretest differences, but it cannot eliminate selection bias or unmeasured confounding. The study also included only two classrooms from a single public school and a relatively small sample, which limits generalizability. Accordingly, the adjusted between-group differences should be interpreted as preliminary quasi-experimental evidence rather than definitive causal estimates. The fact that follow-up measurement was available only for the experimental group also means that the follow-up findings should be interpreted as within-group evidence of the maintenance of gains. Emotion regulation in this article was assessed using adult-reported measures. This choice was intended to provide an alternative assessment source by capturing adults' observations of children's emotion regulation patterns in everyday contexts; however, the future use of child self-report together with other measurement sources may contribute to a more comprehensive examination of these findings. Finally, because emotion regulation was not the primary goal of the intervention, it is more appropriate to consider the results in this area as potential secondary/transfer effects rather than direct effects.

Conclusion

In conclusion, this study suggests that a classroom-based WMTP can support children's working memory development and may also have positive implications for emotion regulation, although these findings warrant greater caution. The strongest effects were observed for the cognitive outcomes directly targeted by the intervention, while gains related to emotion regulation should be considered possible secondary or transfer effects. However, the correlational findings between working memory and emotion regulation suggest that these two areas may be linked through common self-regulation processes. In this respect, the study demonstrates that an intervention conducted in a real school context can have both theoretical and practical value and underscores the importance of considering cognitive support programs in the early school years in relation to broader developmental outcomes.

Recommendations

The findings of this study suggest that structured working memory activities in early elementary school can be considered a viable school-based approach that not only supports cognitive skills but also contributes to children's broader foundation for self-regulation. However, such programs are better viewed not as direct emotion regulation interventions but primarily as supportive practices that



target cognitive control processes and may provide secondary gains in emotion regulation. In terms of implementation, age-appropriate program structure, sufficient implementation time, careful program preparation, and close monitoring of the implementation process are important. Future research could contribute to the field by re-examining these findings in different school contexts and with more diverse samples, addressing follow-up measures more comprehensively, and supporting emotion regulation findings with multiple sources of information. Furthermore, studies examining the conditions under which the relationship between working memory and emotion regulation becomes more pronounced could help clarify these findings.

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Ethics and Conflict of Interest

The study received ethical approval from the Scientific Publication and Ethics Committee of Gazi University (No. E.585142, dated 09/02/2023) and official implementation permission from the Ministry of National Education (No. E.74258403, dated 12/04/2023). The research was conducted in accordance with relevant ethical principles. Written informed consent was obtained from parents, and child assent was obtained from participating children. The authors declare that there are no conflicts of interest regarding the research, authorship, and/or publication of this article.

Author Contribution

This article is derived from the first author's doctoral dissertation titled "Examining the Effects of a Working Memory Training Program on Emotion Regulation and Working Memory Skills of Second-Grade Students" completed at Gazi University in December 2025 under the supervision of the second author. Emire Uluğ: Conceptualization, methodology, investigation, data curation, formal analysis, development and implementation of the intervention, and writing—original draft. Ayşe Dilek Öğretir Özçelik: Supervision, methodology, validation, and writing—review and editing. Both authors read and approved the final manuscript.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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APPENDICES

Supplementary Table S1.

Follow-up outcomes within the intervention group (pretest–posttest–follow-up)

Outcome	Pretest M (SE) [95% CI]	Posttest M (SE) [95% CI]	Follow-up M (SE) [95% CI]	F(df1, df2)	p	η^2	Pre- Post p	Post- FU p	Pre- FU p
Total working memory	18.00 (1.56) [14.76, 21.24]	25.09 (1.81) [21.33, 28.85]	26.50 (1.92) [22.51, 30.49]	64.59 (2, 42)	< .001	.755	< .001	.103	< .001
Verbal working memory*	2.73 (.34) [2.02, 3.44]	4.00 (.40) [3.17, 4.83]	4.36 (0.55) [3.22, 5.50]	11.46 (1.504, 31.577)	< .001	.353	< .001	.913	.004
Visual working memory*	3.09 (.57) [1.90, 4.28]	5.00 (.51) [3.94, 6.06]	4.77 (.46) [3.80, 5.74]	13.80 (1.268, 26.629)	< .001	.397	.002	.782	.004
Emotion regulation –total (adult form)	70.86 (2.90) [64.84, 76.88]	79.55 (3.07) [73.17, 85.93]	79.00 (2.83) [73.11, 84.89]	30.03 (1.083, 22.734)	< .001	.588	< .001	.921	< .001

Note. FU = follow-up. Pairwise comparisons are Bonferroni-adjusted. Follow-up data were available only for the intervention group; therefore, maintenance was evaluated within the intervention group and could not be tested



comparatively against the control group.

*Greenhouse–Geisser corrected degrees of freedom were reported due to sphericity violations.

Follow-up (retention) analyses conducted within the intervention group ($n = 22$) indicated significant time effects for all outcomes, suggesting meaningful change from pretest to posttest and the follow-up period. Total working memory showed a significant effect of Time, $F_{(2, 42)} = 64.59$, $p < .001$, $\eta^2 = .755$; Bonferroni-adjusted comparisons indicated a significant increase from pretest to posttest ($p < .001$) and from pretest to follow-up ($p < .001$), while the posttest–follow-up difference was not significant ($p = .103$), supporting maintenance of gains. Verbal working memory also demonstrated a significant time effect with Greenhouse–Geisser correction, $F_{(1.504, 31.577)} = 11.46$, $p < .001$, $\eta^2 = .353$; scores improved from pretest to posttest ($p < .001$) and remained higher at follow-up relative to pretest ($p = .004$), with no significant change from posttest to follow-up ($p = .913$), indicating maintenance. Similarly, visual working memory showed a significant corrected time effect, $F_{(1.268, 26.629)} = 13.80$, $p < .001$, $\eta^2 = .397$; pretest-to-posttest ($p = .002$) and pretest-to-follow-up ($p = .004$) improvements were significant, whereas posttest and follow-up did not differ ($p = .782$), again suggesting maintained gains. Finally, adult emotion regulation (total) displayed a significant corrected time effect, $F_{(1.083, 22.734)} = 30.03$, $p < .001$, $\eta^2 = .588$; scores increased from pretest to posttest ($p < .001$) and from pretest to follow-up ($p < .001$), with no significant posttest–follow-up difference ($p = .921$), consistent with maintenance. Because follow-up data were available only for the intervention group, these retention findings reflect within-group maintenance and cannot be interpreted as comparative long-term effects relative to the control group.