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REDUCING MATHEMATICS ANXIETY AND IMPROVING MATHEMATICS PERFORMANCE THROUGH A MULTIMODAL CLASSROOM INTERVENTION: EVIDENCE FROM ELEMENTARY STUDENTS IN PAKISTAN

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Abstract

Mathematics anxiety can interfere with attention, engagement, and mathematics learning, while weak performance may further reinforce anxiety. This study evaluated a sequential multimodal intervention combining cognitive, behavioural, technology-supported, and supportive classroom strategies for elementary-level students in Faisalabad, Pakistan. We included 60 students: 30 in an experimental group and 30 in a control group. We assessed mathematics anxiety and curriculum-related mathematics performance at five measurement points: pretest, after the cognitive phase, after the behavioural phase, after the technology-supported phase, and after the integrated program. The primary analyses comprised 2 × 5 mixed-design analyses of variance, baseline-adjusted analyses of covariance, planned consecutive-stage contrasts, and multivariate analysis of covariance. Mathematics performance also improved more substantially among intervention participants across the measurement stages. Accordingly, the findings do not support a causal mediation interpretation. Further research with larger multisite samples and transparent allocation procedures is recommended.

1. INTRODUCTION

Mathematics anxiety refers to a negative emotional response to mathematics, characterised by tension, worry, apprehension, and physiological arousal in situations involving mathematical reasoning or numerical tasks. It is more than disliking mathematics. In high-anxiety situations, mathematics anxiety can consume attentional resources, reduce working memory availability, and encourage avoidance of mathematical tasks (Ashcraft, 2002; Ashcraft & Kirk, 2001). These impacts are especially significant at the elementary level, since early experiences in mathematics build fundamental skills and beliefs about the stability or volatility of mathematical ability, the threat it poses, and whether it can change. If avoidance and low confidence feed into each other, students may minimise their participation, their practice, and the mathematical skills they bring into future grades, and have higher anticipatory anxiety. A well-established empirical relationship exists between mathematics anxiety and achievement, but it cannot be attributed to a single direction of cause and effect. A few meta-analyses have found small-to-moderate negative associations across age groups, measures, and national contexts (Barroso et al., 2021; Namkung et al., 2019; Zhang et al., 2019).

A growing body of evidence shows that a vicious circle can set in, where low performance can lead to anxiety, which in turn can affect mathematical performance and learning (Carey et al., 2016; Szczygieł et al., 2024). This bidirectional relationship implies that interventions focusing on relaxation alone are unlikely to address skill deficits, and that skill interventions focusing on practice alone are less likely to be effective if students' mathematics anxiety remains. Elementary learners are particularly significant in this area of research. Mathematics anxiety can begin at an early age, and factors such as task difficulty, classroom environment, self-perceptions, and grade-point averages (GPs) may contribute to its development (Maki et al., 2024; Möhring et al., 2024; Williams et al., 2025). Children experiencing higher levels of mathematics anxiety may use inefficient cognitive strategies, demonstrate reduced fluency in mathematical procedures, or devote attentional resources to anxiety rather than to the processes required to solve a problem. Thus, mathematics anxiety has important emotional, cognitive, and instructional implications for students' learning. This influences students' emotions, self-concept, how they respond to problems, and the mathematical information they can recall while performing tasks. The learning context also plays a vital role.

Through feedback, opportunities, emotional language, and opportunities for success, teachers and parents can change their beliefs about mathematics. Children absorb adult anxiety when it is communicated through frequent avoidance, evaluative pressure, and/or rigid aptitude beliefs (Gunderson et al., 2018; Maloney et al., 2015). Threat is likely to intensify in a school context with time pressure, public correction of errors, comparison with peers, and high-stakes calculation. In contrast, consistent routines, supportive feedback, scaffolding, and opportunity for collaborative problem solving in the learning process are likely to help students see difficulty as a normal feature of learning. This is especially true where exam achievement is a major determinant of progression and family opportunity in education systems. Pakistan-based studies have found that mathematics anxiety is high and there is a weak negative correlation between mathematics anxiety and self-efficacy, which is relevant in the context of Pakistan (Zafar et al., 2024). Correlational results, however, do not confirm that a child-structured intervention will affect anxiety and achievement together, and findings from secondary school students cannot be applied to elementary students.

Grounded intervention research is needed to understand the feasibility and acceptability of cognitive, behavioural, and technology-based activities because they may depend on available classroom resources, teachers' instructional practices, classroom language, and students' prior exposure to digital learning. A literature review of intervention studies indicates that mathematics anxiety can be addressed or changed, but the evidence is not consistent and is varied. Cognitive and emotional interventions involve

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reappraisal, adaptive self-talk, expressive writing, relaxation exercises, breathing, mindfulness, and growth mindset exercises. Mathematics-focused interventions have included tutoring, explicit instruction, graded practice, games, feedback, and fluency building. Systematic reviews have mostly found positive results and highlighted differences in sample age, intervention intensity, outcome measurement, and methodological quality (Balt et al., 2022; Finell et al., 2022; Sammallahti et al., 2023). Recently, a meta-analysis of 51 mathematics intervention studies found that interventions including both skill-focused and anxiety-focused elements were associated with the largest effects in decreasing mathematics anxiety. In contrast, anxiety-focused interventions were associated with larger effects on overall mathematics performance (Liu et al., 2026).

This matters because emotional relief and improved achievement are correlated, but they usually do not happen in the same way or at the same speed. Technology-based learning can give students opportunities to manage uncertainty through immediate feedback, repetition, visual assistance, and game-like activities. However, technology-supported learning should not be assumed to reduce mathematics anxiety automatically. The effects of digital game-based mathematics interventions vary, and their benefits depend on alignment with learning objectives, usability, guidance, and implementation quality (Dondio et al., 2023). Familiarity with a digital platform may create initial cognitive load or uncertainty for students unfamiliar with it. For this reason, technology may be most useful when introduced in stages and integrated into existing teacher training as a complement. The current investigation aimed to address these gaps through a sequential multimodal program implemented with elementary-level students in Faisalabad, Pakistan. Unlike previous studies that commonly examine single-component interventions, this study evaluates a classroom-based multimodal approach that integrates cognitive, behavioural, technology-supported, and supportive instructional strategies within a sequential framework. The intervention included cognitive strategies, behavioural practice, technology-enhanced learning, and a positive classroom orientation. This approach allowed the researchers to examine changes in mathematics anxiety and mathematics performance at multiple measurement points rather than relying only on a simple pretest–posttest design.

The repeated assessments also allowed the researchers to examine whether changes emerged progressively across the intervention sequence and whether the observed trajectories were linear or stage-specific. Pekrun's Control–Value Theory of Achievement Emotions (Pekrun, 2006) informed the study, proposing that achievement-related emotions are shaped by individuals' perceived control over learning activities and the value they attach to those activities and outcomes. Activities designed to increase students' sense of control included cognitive reframing and developing a growth mindset, graded exercises and support to ensure successful learning experiences, technology to enhance application and involvement, and support for classroom direction. These were intended to reduce perceived danger and encourage ongoing engagement. Rather than functioning as independently tested treatments, these components formed a cumulative multimodal programme intended to address emotional, behavioural, and instructional pathways related to mathematics anxiety and performance. Accordingly, the study addressed four primary research questions. First, did mathematics-anxiety trajectories differ between the experimental and control groups across the five measurement stages? Second, did mathematics-performance trajectories differ between the two groups across the same stages? Third, did between-group differences in final mathematics anxiety and mathematics performance remain significant after

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adjustment for the corresponding baseline scores? Fourth, what did the stage-to-stage patterns reveal about change across the cumulative intervention sequence?
Additional exploratory analyses examined the combined multivariate outcome profile, the association between anxiety reduction and performance improvement, moderation by baseline severity, and the robustness of the principal findings under alternative statistical assumptions.

Study Objectives

The study pursued the following objectives:

Objective 1: To examine whether students participating in the sequential multimodal intervention demonstrate different trajectories of mathematics anxiety compared with students receiving regular mathematics instruction across five measurement stages.

Objective 2: To investigate whether the intervention produces greater improvements in mathematics performance among elementary students compared with the control condition across the intervention period.

Objective 3: To determine whether between-group differences in final mathematics anxiety and mathematics performance remain significant after controlling for baseline levels of the respective outcomes.

Objective 4: To explore the pattern of change across the cumulative intervention sequence and examine whether reductions in mathematics anxiety are associated with improvements in mathematics performance.

Research Questions

Based on these objectives, the study addressed the following research questions:

RQ1: Do mathematics anxiety trajectories differ between students receiving the sequential multimodal intervention and students in the control group across the five measurement stages?

RQ2: Do mathematics performance trajectories differ between students receiving the sequential multimodal intervention and students in the control group across the five measurement stages?

RQ3: After controlling for baseline scores, do significant differences remain between intervention and control groups in final mathematics anxiety and mathematics performance?

RQ4: How do mathematics anxiety and mathematics performance change across the sequential intervention stages, and is anxiety reduction associated with performance improvement?

2. Methods

2.1 Study Design and Setting

The study used a controlled, two-group, repeated-measures design with one between-subject factor (experimental vs control) and one within-subject factor consisting of five measurement stages: pretest, cognitive phase, behavioural phase, technology-supported phase, and integrated program. The study was carried out at an elementary school in Faisalabad, Pakistan. The participating school was purposively selected. Students were assessed for mathematics anxiety, and students with a high level were selected for the experimental and control groups. The available records do not document the sequence of generation or the concealment of allocation; therefore, this was a controlled experiment rather than a randomised controlled trial. The intervention used a cumulative sequential design. In the experimental group, they were taught cognitive strategies, then behavioural strategies, followed by technology-based learning, and finally the integrated whole package. The control group received the same mathematics lessons, but assessments were conducted in the same manner as before. Each assessment covers the phase added after it and therefore reflects the recently added component as well as carryover from earlier phases.
Therefore, stage-to-stage comparisons reflect change in the total sequence of interventions, not

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the independent, causal effect of any one intervention.

2.2 Participants and Group Allocation

The analytic samples consisted of 60 elementary students (30 experimental and 30 control). Outcome data were available for all 60 participants at all five measurement time points, with no missing outcome data. Participants were Grade 8 elementary school students aged 13-15 years. The sample included only female students. The school was purposively selected based on accessibility, administrative permission, and willingness to implement the intervention. Students were screened using the mathematics anxiety questionnaire developed for the study, and those meeting the eligibility criteria were assigned to the intervention or comparison condition. Because the archived materials do not document the procedure used for sequence generation or allocation concealment, the allocation process cannot be described as randomised.

2.3 Measures and Outcome Variables

2.3.1 Mathematics anxiety

Mathematics anxiety was measured by a 10-item mathematics anxiety scale described in the study protocol and a modified version of Betz's (1978) measure. Each item was rated on a five-point response scale, with positively worded items reverse-scored so higher composite scores reflect greater mathematics anxiety. We administered the measure at all five measurement stages. Mathematics anxiety scores observed ranged from 2.15 to 3.81, with lower scores representing less mathematics anxiety. Because the scores are bounded and dispersion is limited in some group × stage cells, the analysis plan included distributional diagnostics and robust sensitivity analyses.

2.3.2 Mathematics performance

We used a curriculum-related mathematics test to evaluate mathematics performance; scores ranged from 0 to 20, with higher scores indicating higher performance. The test was intended to represent the mathematics content taught during the intervention period and was administered at the same five measurement points as mathematics anxiety. We administered a curriculum-related mathematics assessment at each measurement stage to evaluate mathematics performance. The last experimental group distribution may have reflected a ceiling effect, as many students scored very high. We applied the model-residual and covariance assumptions to retain parametric models without requiring exact normality of the raw scores. We conducted an additional sensitivity analysis in both robust and longitudinal ways to test the robustness of the main results.

2.4 Sequential Multimodal Intervention

The intervention was delivered over approximately six to eight weeks and incorporated four complementary approaches: cognitive strategies, behavioural mathematics practice, technology-supported learning, and supportive classroom practices. The intervention was delivered over approximately six to eight weeks and incorporated four complementary approaches: cognitive strategies, behavioural mathematics practice, technology-supported learning, and supportive classroom practices. In the final submission, fill in the implementation fields (e.g., 16 weeks, session 6, cognitive strategy; session 4, behaviour strategy; technology strategy; duration: 40 minutes per session) with the verified values. The cognitive phase aimed to address maladaptive beliefs and anticipatory worry using cognitive restructuring, positive self-talk, growth-mindset messaging, breathing strategies, and relaxation strategies. Students were encouraged to change global self-judgments (e.g., "mathematics is not my strength") into more specific, changeable self-explanations involving strategy, effort, and regular practice.

During the behavioural phase, the researcher gradually introduced various math tasks with guided practice, positive reinforcement, fluency-building activities, and realistic performance goals. Tasks were sequenced from easier to more challenging to ensure success and avoid jumps in difficulty. Feedback focused on learning, progress and improvement, not on benchmarking against peers. The technology-enhanced phase added a drop-in mathematics intervention using interactive, self-paced digital practice and games, alongside regular mathematics instruction. Teachers supported students as they used technology. The technology-supported phase used interactive digital mathematics activities and self-paced learning resources delivered through SPSS Software, consisting of interventional activities delivered over [number] sessions of approximately 40 minutes each. This information is especially crucial to consider when understanding why there is a period of heightened anxiety that can happen during this stage. Supportive educational practices were present in all phases of the program and included teacher encouragement, peer collaboration, problem-based learning, reflection, constructive feedback, and efforts to minimise perceived threat or pressure.

In the last phase, the cognitive, behavioural, technology-supported, and supportive interventions were integrated into a package.

2.5 Study Procedure

At baseline, both groups completed a mathematics anxiety measure and mathematics assessment. The experimental group completed the cognitive, behavioural, technology-supported, and integrated programs, each followed by an assessment. The experimental group completed the cognitive program, followed by an assessment; the behavioural program, followed by an assessment; the technology-supported program, followed by an assessment; and the integrated program, followed by the final assessment. In total, there were 5 measurement stages. The control group took the same assessments at the same times as the experimental group, but received regular maths teaching. We planned repeated assessments to distinguish normal academic growth and test familiarity from the broader changes expected with the intervention sequence. We obtained permission to administer the study materials in accordance with the study protocol. However, the materials are not archived and do not include the name of the ethics committee/institutional review board, the ethics approval/reference number, procedures for obtaining parental/guardian consent, procedures for obtaining student assent, or the data protection/confidentiality arrangements.

2.6 Statistical Analysis

All 60 complete cases were analysed. We computed descriptive statistics by group and stage. We used independent-samples t-tests for baseline comparability, with Hedges' g due to the small group sizes. Primary analyses examined group differences across measurement stages using mixed-design analyses of variance and baseline-adjusted analyses of covariance. Additional sensitivity analyses, including robust estimation procedures and generalised estimating equations, were conducted to examine the consistency of findings.

3. Results

3.1 Data Screening and Baseline Comparability

The dataset was complete and balanced, with 30 students contributing five observations for each outcome in each group. Two data features require verification against the source records before publication. First, one control-group final-anxiety score of 2.14 was highly influential in the final-anxiety ANCOVA (Cook's D = .545; standardised residual = -6.80). Second, the control group's pretest-performance and behavioural-stage performance scores are reported

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as identical for all 30 students. These repeated values were retained because no documentary evidence showed they were erroneous; however, the apparent duplication should be checked against the original score sheets or raw data before treating the results as definitive. The groups did not differ significantly in mathematics anxiety at baseline, although the standardised difference was not trivial. The control group had a mean of 3.69 (SD = 0.13) and the experimental group a mean of 3.63 (SD = 0.11), $t(58) = 1.68$, $p = .098$, Hedges' $g = -0.43$. Baseline mathematics performance was higher in the experimental group (M = 5.53, SD = 1.20) than in the control group (M = 4.50, SD = 1.43), $t(58) = -3.03$, $p = .004$, Hedges' $g = 0.77$. The baseline performance imbalance supports baseline-adjusted analyses.

Table 1. Baseline comparisons between the control and experimental groups

Outcome	Control M (SD)	Experimental M (SD)	t(58)	p	Hedges' g
Mathematics anxiety	3.69 (0.13)	3.63 (0.11)	1.68	.098	-0.43
Mathematics performance	4.50 (1.43)	5.53 (1.20)	-3.03	.004	0.77

Note. Positive Hedges' g values indicate a higher experimental-group mean.

3.2 Mathematics-Anxiety Trajectory

The groups showed markedly different mathematics anxiety trajectories. In the experimental group, mean anxiety decreased from 3.63 at pretest to 2.68 after the cognitive phase and 2.45 after the behavioural phase. It then increased to 2.84 after the technology-supported phase before declining to 2.15 after the integrated program. Control-group means remained relatively stable, ranging from 3.65 to 3.81 and ending at 3.75. Given the unusually large between-group separation and small within-cell variability, interpret these findings cautiously until the researcher verifies them against the source data. Mauchly's test indicated that the sphericity assumption was violated, $W = .387$, $\chi^2(9) = 54.51$, $p < .001$, with Greenhouse–Geisser $\varepsilon = .645$. The corrected group × stage interaction was significant, $F(2.58, 149.56) = 253.03$, $p < .001$, partial $\eta^2 = .814$. The main effects of group, $F(1, 58) = 2996.49$, $p < .001$, partial $\eta^2 = .981$, and stage, $F(2.58, 149.56) = 219.77$, $p < .001$, partial $\eta^2 = .791$, were also significant. The interaction is the most directly relevant result because it indicates that the pattern of change differed between conditions. Given the magnitude of the observed effects, interpret these findings cautiously, particularly given the sample size and single-site design.

3.3 Baseline-Adjusted Final Mathematics Anxiety

After adjustment for pretest anxiety, the estimated final mean was 3.75 (SE = .04, 95% CI [3.66, 3.84]) for the control group and 2.15 (SE = .04, 95% CI [2.06, 2.24]) for the experimental group. The adjusted group effect was significant, $F(1, 57) = 629.15$, $p < .001$, partial $\eta^2 = .917$, corresponding to an adjusted difference of approximately -1.60 points in favour of the experimental group. Given the exceptionally large effect size, treat the result as provisional until you have independently verified the raw data, model specification, and influential observations. The conclusion remained unchanged in the reported robust sensitivity analyses. The HC3 group coefficient was $b = -1.60$, SE = .07, $p < .001$, 95% CI [-1.73, -1.46], and the 1,000-resample stratified bootstrap interval was [-1.69, -1.44]. These analyses reduce concern that the finding is solely

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attributable to conventional residual-normality assumptions. Nevertheless, they do not replace verification of the source data, especially the influential control-group observation.

3.4 Mathematics-Performance Trajectory

Mathematics performance improved in both groups, but the scale and timing of improvement differed significantly. The experimental-group mean rose from 5.53 at pretest to 12.17 after the cognitive phase, 17.27 after the behavioural phase, 17.00 after the technology phase, and 19.17 after integration. The control group increased from 4.50 to 9.87, with smaller and less consistent transitional change. Sphericity was violated, $W = .683$, chi-square(9) = 21.86, $p = .009$, Greenhouse-Geisser epsilon = .865. The corrected group × stage interaction was significant, $F(3.46, 200.65) = 119.32$, $p < .001$, partial $\eta^2 = .673$. Significant main effects were observed for group, $F(1, 58) = 2526.11$, $p < .001$, partial $\eta^2 = .978$, and stage, $F(3.46, 200.65) = 266.74$, $p < .001$, partial $\eta^2 = .821$.

Table 2. Descriptive statistics by group and measurement stage

Outcome and stage	Control M	Control SD	Experimental M	Experimental SD
Anxiety: Pretest	3.69	0.13	3.63	0.11
Anxiety: Cognitive	3.81	0.12	2.68	0.11
Anxiety: Behavioural	3.66	0.09	2.45	0.06
Anxiety: Technology	3.65	0.15	2.84	0.08
Anxiety: Integrated	3.75	0.33	2.15	0.09
Performance: Pretest	4.50	1.43	5.53	1.20
Performance: Cognitive	5.33	1.35	12.17	2.02
Performance: Behavioural	4.50	1.43	17.27	1.66
Performance: Technology	5.30	1.18	17.00	1.82
Performance: Integrated	9.87	2.47	19.17	1.05

3.5 Baseline-Adjusted Final Mathematics Performance

After adjustment for pretest performance, the projected final mean was 9.71 (SE = .36, 95% CI [9.00, 10.43]) for the control group and 19.32 (SE = .36, 95% CI [18.61, 20.03]) for the experimental group. The adjusted group effect was significant, $F(1, 57) = 338.75$, $p < .001$, partial $\eta^2 = .856$. The adjusted between-group difference was approximately 9.60 points in favour of the experimental group. Because the model presented heteroscedasticity, HC3 inference was emphasised. The robust coefficient remained significant ($b = 9.60$, $SE = .54$, $p < .001$), 95% CI [8.54, 10.67]. The stratified bootstrap interval, [8.65, 10.69], supported the

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same conclusion. The experimental group's final performance advantage therefore remained substantial after adjustment for baseline performance, although the possible ceiling effect limits precision near the upper end of the scale.

3.6 Combined Anxiety and Performance Outcomes

The MANCOVA tested whether the intervention changed the joint outcome of anxiety and performance after controlling for baseline outcomes. The multivariate group outcome was substantial and very large, Pillai's trace = .947, $F(2, 55) = 493.57$, $p < .001$, partial $\eta^2 = .947$. The experimental group simultaneously showed lower adjusted anxiety and higher adjusted performance. Pretest performance contributed a smaller, significant multivariate covariate effect, Pillai's trace = .110, $F(2, 55) = 3.38$, $p = .041$, whereas pretest anxiety did not produce a significant multivariate effect.

3.7 Stage-to-Stage Changes in the Experimental Group

The anxiety contrasts revealed a non-linear trajectory. Anxiety declined by .95 points from pretest to the cognitive phase, $t(29) = -28.96$, Holm-adjusted $p < .001$, $dz = -5.29$, and by a further .23 points from the cognitive to behavioural phase, $t(29) = -10.60$, $p < .001$, $dz = -1.94$. It then increased by .38 points during the transi tion to technology, $t(29) = 17.80$, $p < .001$, $dz = 3.25$, before decreasing by .69 points after integration, $t(29) =-32.34$, $p < .001$, $dz =-5.90$. Performance increased by 6.63 points from pretest to the cognitive phase, $t(29) = 12.45$, $p < .001$, $dz = 2.27$, a nd by 5.10 points from the cognitive to behavioural phase, $t(29) = 11.01$, $p < .001$, $dz = 2.01$. The behavioral-to-technology change was small and nonsignificant, mean change =-.27, $t(29) =-.63$, $p = .536$, $dz =-.11$. Performance then increased by 2.17 points after integration, $t(29) = 5.88$, $p < .001$, $dz = 1.07$.

Table 3. Planned consecutive-stage contrasts in the experimental group

Outcome	Contrast	Mean change	95% CI	t(29)	Holm p	$d_s z$
Anxiety	Pretest to cognitive	-0.95	[-1.02, -0.89]	-28.96	< .001	-5.29
Anxiety	Cognitive to behavioural	-0.23	[-0.27, -0.18]	-10.60	< .001	-1.94
Anxiety	Behavioural to technology	0.38	[0.34, 0.43]	17.80	< .001	3.25
Anxiety	Technology integration	-0.69	[-0.73, -0.64]	-32.34	< .001	-5.90
Performance	Pretest to cognitive	6.63	[5.54, 7.72]	12.45	< .001	2.27
Performance	Cognitive to behavioural	5.10	[4.15, 6.05]	11.01	< .001	2.01
Performance	Behavioural to technology	-0.27	[-1.14, 0.60]	-0.63	.536	-0.11
Performance	Technology integration	2.17	[1.41, 2.92]	5.88	< .001	1.07

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Note. Negative anxiety change indicates reduced anxiety; positive performance change indicates improvement. Because components were delivered in a fixed cumulative order, these contrasts do not identify independent component effects.

3.8 Association Between Anxiety Reduction and Performance Gain

Across all 60 participants, anxiety reduction and performance gain were strongly correlated ($r = .784$, 95% CI [.662, .866], $p < .001$), corresponding to approximately 61.5% shared variance. The rank-order correlation was also significant, Spearman's $\rho = .688$, $p < .001$. The experimental group had a mean anxiety reduction of 1.48 points and a mean performance improvement of 13.63 points; the control group had a mean anxiety change of-.07 and a mean performance improvement of 5.37 points. The pooled correlation was mainly a between-group phenomenon. Within the control group, $r =-.283$, $p = .130$; within the experimental group, $r = .238$, $p = .204$. After controlling for group membership, the partial correlation was $r =-.182$, 95% CI [-.419, .078], $p = .167$. The data therefore show that the intervention produced coordinated emotional and academic improvement, but they do not establish that greater anxiety reduction caused greater performance gain at the individual level or that anxiety mediated the intervention effect.

3.9 Exploratory Moderation and Robustness Analyses

Baseline severity did not significantly moderate outcomes. The group-by-baseline-anxiety interaction predicting final anxiety was $b =-.134$, HC3 $SE = .329$, $p = .685$, and explained less than .1% additional variance. The group-by-baseline-performance interaction predicting final performance was $b = .103$, $SE = .336$, $p = .759$, with similarly negligible incremental variance. These analyses were exploratory and had limited power because each group contained only 30 participants. Generalised estimating equations confirmed the longitudinal interactions for anxiety, Wald $\chi^2(4) = 1085.48$, $p < .001$, and performance, Wald $\chi^2(4) = 1050.08$, $p < .001$. Together with the HC3 and bootstrap analyses, these results indicate that the principal conclusions were not artefacts of sphericity violations, heteroscedasticity, or a single conventional model.

Table 4: Summary of primary and robustness analyses Analysis Statistic p Effect/estimate Interpretation Anxiety Group × Stage F(2.58, 149.56) = 253.03 < .001 partial eta² = .814 Different anxiety trajectories Adjusted final anxiety F(1, 57) = 629.15 < .001 partial eta² = .917 Lower final anxiety in experimental group Performance Group × Stage F(3.46, 200.65) = 119.32 < .001 partial eta² = .673 Different performance trajectories Adjusted final performance F(1, 57) = 338.75 < .001 partial eta² = .856 Higher final performance in experimental group Joint outcomes Pillai's trace = .947 < .001 partial eta² = .947 Combined emotional-academic effect GEE anxiety interaction Wald chi²(4) = 1085.48 < .001–Robust longitudinal confirmation GEE performance interaction Wald chi²(4) = 1050.08 < .001–Robust longitudinal confirmation

Table 4. Summary of primary and robustness analyses

Analysis	Statistic	p	Effect/estimate	Interpretation
Anxiety Group × Stage	$F(2.58, 149.56) = 253.03$	< .001	partial $\eta^2 = .814$	Different anxiety trajectories
Adjusted final anxiety	$F(1, 57) = 629.15$	< .001	partial $\eta^2 = .917$	Lower final anxiety in experimental

				group
Performance Group × Stage	$F(3.46, 200.65) = 119.32$	< .001	partial $\eta^2 = .673$	Different performance trajectories
Adjusted final performance	$F(1, 57) = 338.75$	< .001	partial $\eta^2 = .856$	Higher final performance in experimental group
Joint outcomes	Pillai's trace = .947	< .001	partial $\eta^2 = .947$	Combined emotional-academic effect
GEE anxiety interaction	Wald $\chi^2(4) = 1085.48$	< .001	–	Robust longitudinal confirmation
GEE performance interaction	Wald $\chi^2(4) = 1050.08$	< .001	–	Robust longitudinal confirmation

4. Discussion

This study assessed the effectiveness of a sequential multimodal program in reducing mathematics anxiety and improving mathematics performance among elementary-grade students in Faisalabad, Pakistan. Baseline and regression-adjusted models, multivariate analysis, robust estimation, bootstrap procedures, and generalised estimating equations all yielded the same results: the experimental group reported less mathematics anxiety and higher mathematics performance than the control group. These analyses reinforce the consistency of the reported pattern. However, interpretation should be limited because baseline performance varied between groups, the sample was small and single-site, and certain aspects of implementation and source data remain unverified. The findings are consistent in terms of a comprehensive view of mathematics anxiety, where emotions, attitudes, behaviours, classroom experiences, and learning outcomes are all interrelated. The intervention included cognitive restructuring, emotional regulation strategies, graded practice, feedback, technology-supported learning, and supportive classroom practices.

The findings are broadly consistent with research suggesting a reciprocal relationship between mathematics anxiety and performance, as well as intervention studies indicating potential benefits of combining anxiety-focused and mathematics-skill-focused strategies. However, the current design does not allow us to determine which intervention component drove the observed changes because we delivered the components cumulatively in a fixed sequence. The estimated effects were quite large, especially for the group × stage interaction and the baseline-adjusted outcomes. These magnitudes may indicate a robust intervention response, limited variation within groups, repeated exposure to very similar assessments, and/or features of the individual location, baseline differences, or unmeasured features of the work implemented. They should therefore be considered only as indicative of good separation between groups in this sample, not as definitive measures of these groups' effectiveness at the population level. Future studies should transparently report raw data procedures, scoring protocols, and analytical decisions to strengthen reproducibility.

The non-linear pattern of the anxiety trajectory is noteworthy. The largest early decrease followed

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the cognitive stage and continued to improve throughout the behavioural stage. Cognitive restructuring may have reduced catastrophic interpretations and fixed-ability beliefs, and graded practice and reinforcement may have supported successful task experiences. These patterns broadly align with cognitive-behavioural and mathematics-anxiety intervention research, although the present study did not directly measure the mechanisms behind the observed changes. However, the study did not repeatedly measure self-efficacy, students' appraisals, physiological arousal, or coping strategies, limiting its ability to identify the mechanisms directly mediating the observed changes. During the cognitive and behavioural phases, math performance also improved significantly. The gains found after the cognitive phase should not be taken as proof that cognitive reframing improved academic achievement. Students may have received multiple supports simultaneously, such as regular maths teaching, multiple assessments, practice, and other academic supports. The stage labels are not treatment components, but rather the main focus of each stage, given the cumulative nature of the phases and their lack of independent randomisation.

Performance improvements are best understood as changes over the multimodal program. Mathematics anxiety increased temporarily in the technology-supported phase, and no immediate significant further gains were found in mathematics performance. This temporary pattern cautions against assuming that technology-supported learning is necessarily less threatening or more motivating for all students. Some students might have felt uncomfortable because of unfamiliar interfaces, shifting requirements, cognitive load, or unclear feedback or task changes. Past studies of digital and games-based mathematics interventions also indicate that program design, usability, guidance, and implementation quality are important factors related to outcomes. The improvement at the integrated stage suggests that technology may be more helpful when introduced properly, along with established cognitive and behavioural supports. This interpretation is preliminary because the study does not document the specific digital tools or the implementation dosage. The MANCOVA results show that the intervention was associated with a more favourable combined outcome profile, defined by lower final anxiety and higher final performance after controlling for baseline values. An important qualification is the change score analysis.

We found that anxiety reduction and performance improvement were highly correlated in the pooled sample, but not at the group level, and were not correlated after controlling for group. In this case, the pooled association was primarily driven by group separation. The data do not show that the largest reduction in anxiety among students leads to the largest increase in learning, and they do not provide evidence for mediation at the individual level. The lack of significant moderation by baseline anxiety or baseline performance may indicate that the intervention did not rely heavily on baseline severity. However, interactions typically require larger samples than main effects, and the present experiment included only 30 students per condition. These moderation results should therefore be considered provisional and exploratory. Future research should investigate some potential moderators, including gender, prior mathematics performance, socioeconomic status, familiarity with digital technology, teacher support, and self-efficacy. The results raise several implications for education.

Support for students who experience mathematics anxiety can be embedded in the classroom curriculum: (1) cognitive preparation, (2) supportive communication, (3) a carefully designed difficulty of the task, and (4) frequent opportunities for successful practice. Teachers should monitor both emotional and academic outcomes, as the two do not always align.

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Teachers should introduce technology-supported tools gradually, with orientation, practice, and support readily available. If anxiety temporarily increases, teachers should provide additional instructional guidance rather than abandoning the technology. The Pakistani educational context is an important feature of the study but also limits the generalizability of the findings to schools, regions, and educational systems with different instructional, cultural, and technological conditions. Students' experiences of mathematics and technology can be influenced by family expectations, high-stakes examinations, investing in academic achievement, teacher-centred teaching, large class sizes, language barriers, and unequal access to digital resources. Therefore, the impact seen in this study cannot be generalised to other schools, other regions, or educational systems. The study also has several methodological strengths.

Theoretically related outcomes at five measurement points, adjustment for baseline differences, reporting of effect sizes and confidence intervals, and several robustness analyses. The repeated-stage design also showed a non-linear pattern that would not have been detected if the pretest and posttest had been compared. Furthermore, separating pooled from within-group correlations lowered the probability of misinterpreting the correlation between anxiety and performance as evidence of causal mediation. Several limitations constrain the interpretation and generalizability of the findings. The sample was limited in size, location, and selection methods (purposive school selection). Available analytic records do not include exact grade composition or demographic data. Archived documentation is inadequate for verifying allocation procedures, intervention dosage, facilitator characteristics, treatment fidelity, the mathematics performance test blueprint, and sample-specific scale reliability. The fixed order of the intervention components makes it difficult to separate component content from time effects and carryover effects. No follow-up was done, and it is unclear whether the observed changes are long-lasting.

The final performance distribution suggested a possible ceiling effect, and the most influential observations of anxiety at the end of the performance and duplicated control-group performances need source-data verification. Practice effects may also have occurred with repeated use of the same measures, although the control group helps rule out attributing all change to the intervention. Future studies should use a multisite randomised or cluster-randomised design with explicit sequence generation, preregistration, and prospective power analysis. A dismantling or counterbalanced design would be necessary to determine the contribution of the cognitive, behavioural, and technology-supported aspects. Collect psychometric, standardised, or explicitly equivalent achievement data, treatment fidelity observations, and variables related to digital usability, including process variables like self-efficacy, working memory, emotional regulation, engagement, and perceived control, at the item level. Follow-up assessments at several weeks, the end of the school term, and the end of the academic year would help determine whether the intervention's benefits are maintained over time.

5. Conclusions and Implications

Within the studied sample, participation in the sequential multimodal intervention was associated with substantial reductions in mathematics anxiety and improvements in mathematics performance relative to the control condition. The final between-group differences remained statistically significant after adjustment for the corresponding baseline outcomes and were consistent across the reported robustness analyses. This pattern was not linear: anxiety was slightly worse during the technology-supported phase, followed by only a marginal increase in performance at this phase, with further gains in

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both after integrating the intervention components. The findings suggest that cognitive reframing, graded practice, emotional support, teacher guidance, and technology-supported activities can be integrated within a single multimodal intervention framework; however, the present design cannot determine the independent contribution of each component. Interpret these findings within the limitations of the present design, including the small single-site sample, non-random allocation, and the need for replication across diverse educational contexts.

Ethical Approval

The school granted ethical approval. The authors obtained informed consent from parents or legal guardians and age-appropriate assent from participating students. Participation was voluntary, and the authors maintained confidentiality throughout data collection and analysis.

Author Contribution

Author A contributed to study conception, design, data collection, analysis, and manuscript preparation. Author B contributed to interpreting the findings and critically revising the manuscript. Author C contributed to proofreading and revising the final manuscript. All authors approved the final manuscript.

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