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Enhancing Resilience in Mathematics Education: Evaluating Chinese Targeted Intervention Strategies

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Abstract:

Introduction: This study developed and validated a mathematics-specific resilience intervention program tailored for Chinese university students, integrating Sidek's resilience framework with Delphi method-based expert consensus.

Objectives: To develop the Chinese Mathematics Resilience Interventions; To assess the validity and reliability of the Chinese Mathematics Resilience Interventions; To assess the effects of the Chinese Mathematics Resilience Interventions and control group with no intervention pre-test and post-test.

Methods: Employing a quasi-experimental design with matched experimental (n=40) and control groups (n=40), the 12-week structured intervention demonstrated significant efficacy through repeated-measures ANOVA and the Shapiro-Wilk test.

Results: After controlling baseline scores, the experimental group exhibited statistically enhanced mathematical resilience at post-test ($p < 0.05$, partial $\eta^2 = 0.025$), with sustained effects observed in the 1-month retention test.

Conclusions: These findings advance evidence-based practices for STEM education adaptation, offering a replicable framework that bridges psychological resilience theories with discipline-specific pedagogical needs in Chinese higher education. The program's longitudinal effectiveness underscores its potential as a scalable solution for improving mathematics persistence among undergraduates facing academic adversity.

Keywords: Mathematical resilience, quasi-experimental study, the Chinese Mathematics Resilience Interventions, ANOVA, Wilcoxon analysis

1. Introduction

Mathematics education is shaped by cultural influences. Chinese mathematics education, rooted in traditional culture and Confucianism, possesses both strengths and weaknesses. In our globalized society, the quality of mathematics education is a key determinant of national competitiveness in human resources (Niño & Gómez, 2022). Chinese mathematics teaching, often characterized by repetitive learning and conceptual connections, strengthens both understanding and problem-solving skills. Scholars attribute the success of Chinese students to factors such as precise language, logic, discipline, and the teacher-student relationship (Peng & Cao, 2021). International research indicates that other nations may benefit from China's approach (Huang, 2021). While Chinese mathematics education excels in foundational skills, as evidenced by strong performances in mathematics Olympiads and High International Association for the Evaluation of Educational Achievement (2009, 2012, 2018), concerns remain. The high achievement of Shanghai students, for example, is linked to heavy homework loads and extended study hours, reflecting significant pressure. High International Association for the Evaluation of Educational Achievement data highlights low school identification and overall happiness, underscoring the stressful environment.

However, Chinese mathematics education has areas in need of improvement. Teachers tend to focus heavily on computation and logic, often neglecting real-world applications. This overemphasis on knowledge transfer limits proactive learning (Li & Yeung, 2017). Additionally, emotional engagement in mathematics learning is often lacking, especially when compared to Western counterparts (Mesiti et al., 2021). Graduates often perceive mathematics as disconnected from real-world issues (Sun, 2020). Only a small proportion of teachers and parents understand the broader role of mathematics in shaping basic qualities and the quality of life (Fan et al., 2015).

Introducing the concept of mathematical resilience in the classroom can enhance teaching effectiveness and improve academic performance. Resilience interventions have proven beneficial, particularly in rural and remote regions of China, where unequal access to educational resources persists. In 2023, approximately 560 million people in China lived in rural areas, where students often face significant challenges. Research highlights the role of resilience in educational outcomes. For instance, Cheng (2020) explored resilience in medical students' mental health, while Li and Yeung (2017) connected it to rural students' academic resilience. Further, Ye (2019) demonstrated resilience's moderating effect on stress and academic performance. Resilience also affects language learners' creativity and learning environments (Chen & Padilla, 2022), while Wei (2022) found it influential in English learners' motivation and self-regulation. Resilience research in China has primarily focused on education, mental health, and language learning.

In summary, research underscores the value of enhancing vulnerable students' academic performance through resilience-building strategies, promoting mental well-being, and fostering motivation and happiness. However, a gap exists in applying resilience to the context of mathematics education for Chinese students.

To tackle these challenges, this study develops a Chinese Mathematics Resilience Interventions, grounded in the Sidek Model and structured around four key dimensions: value, struggle, growth, and resilience. The intervention fosters problem-solving skills and real-world applications, enhancing students' confidence and engagement. Its effectiveness is assessed through pre- and post-intervention testing using the Mathematical Resilience Scale.

Classroom resilience interventions have demonstrated success in supporting students under adverse conditions (Apostolidu & Johnston-Wilder, 2023). A resilience-focused approach creates a safe, exploratory learning environment, encouraging students to engage with mathematics without fear (Donolato et al., 2020).

2. Objectives

This study aims to systematically develop a culturally adaptive Chinese Mathematics Resilience Intervention to establish a student psychological support system aligned with local educational ecology. In the initial phase, researchers will integrate cognitive restructuring, meta-strategy training, and peer-assisted learning modules based on positive psychology theory and mathematics education research, forming a multidimensional intervention framework. To ensure the scientific validity of measurement instruments, the research team will employ Delphi expert consultation to evaluate content validity. The internal consistency and temporal stability of intervention modules will be quantitatively assessed using Cronbach's α coefficients and test-retest reliability methods. A standardized implementation protocol with quality control mechanisms will be established to maintain intervention fidelity across different educational contexts.

The efficacy validation phase adopts a quasi-experimental design with longitudinal tracking, utilizing stratified random sampling to select experimental and control group participants. Mixed-effects models will be employed to analyze between-group differences in Mathematics Resilience Scale and mathematics achievement tests across pre-test and post-test intervals, with particular focus on the intervention's mechanisms in enhancing mathematical self-efficacy, optimizing attribution patterns, and strengthening adversity coping strategies. Covariance analysis (ANCOVA) will be incorporated to control baseline differences.A one-month follow-up assessment is specifically designed to examine the sustainability and transferability of intervention effects. These methodological rigor measures will provide empirical evidence for constructing a culturally responsive model for fostering mathematical psychological resilience in China, ultimately contributing to the development of indigenous educational psychology practices.

3. Methods

In this study, the experimental group participated in 12 weeks of the Chinese Mathematics Resilience Interventions, while the control group received traditional teaching methods. Mathematical resilience was assessed in both groups at four time points: prior to the intervention, at the 4th, 8th, and 12th weeks, and one month following the conclusion of the intervention. The effectiveness was evaluated through subsequent data analysis.

This study employing a quasi-experimental design, two classes from the Engineering Faculty were selected from a college in China, with 80 students forming the experimental and control groups. Students represent diverse socioeconomic backgrounds and learning environments, offering a broad range of perspectives for the intervention.

The Mathematics Resilience Scale (MRS), developed by Kooken et al. (2016), is a validated psychometric tool designed to assess students' engagement with mathematics and their perseverance in learning. It evaluates four interrelated factors: Value, Struggle, Growth, and Resilience.

The Chinese Mathematics Resilience Intervention consists of 12 modules delivered over 12 weeks, covering key calculus topics, including derivatives, differentials, integration techniques, and applications of definite and indefinite integrals. Each module comprises a structured framework: title, tools, duration, objectives, theoretical foundation, steps, discussion, summary, and appendix.

Mastery of calculus demands advanced abstract reasoning and problem-solving skills, which are critical across STEM disciplines and beyond. As a cornerstone of STEM education, calculus is typically required for STEM majors and serves as a prerequisite or elective in other fields. Most students encounter calculus in their first or second year, laying the groundwork for more advanced mathematical coursework.

Upon completing the intervention, students will be better equipped to apply calculus concepts to real-world problems while developing logical reasoning, abstraction, and problem-solving abilities—key competencies for both academic and professional success.

The implementation of the Chinese Mathematics Resilience Interventions is structured in two distinct stages.

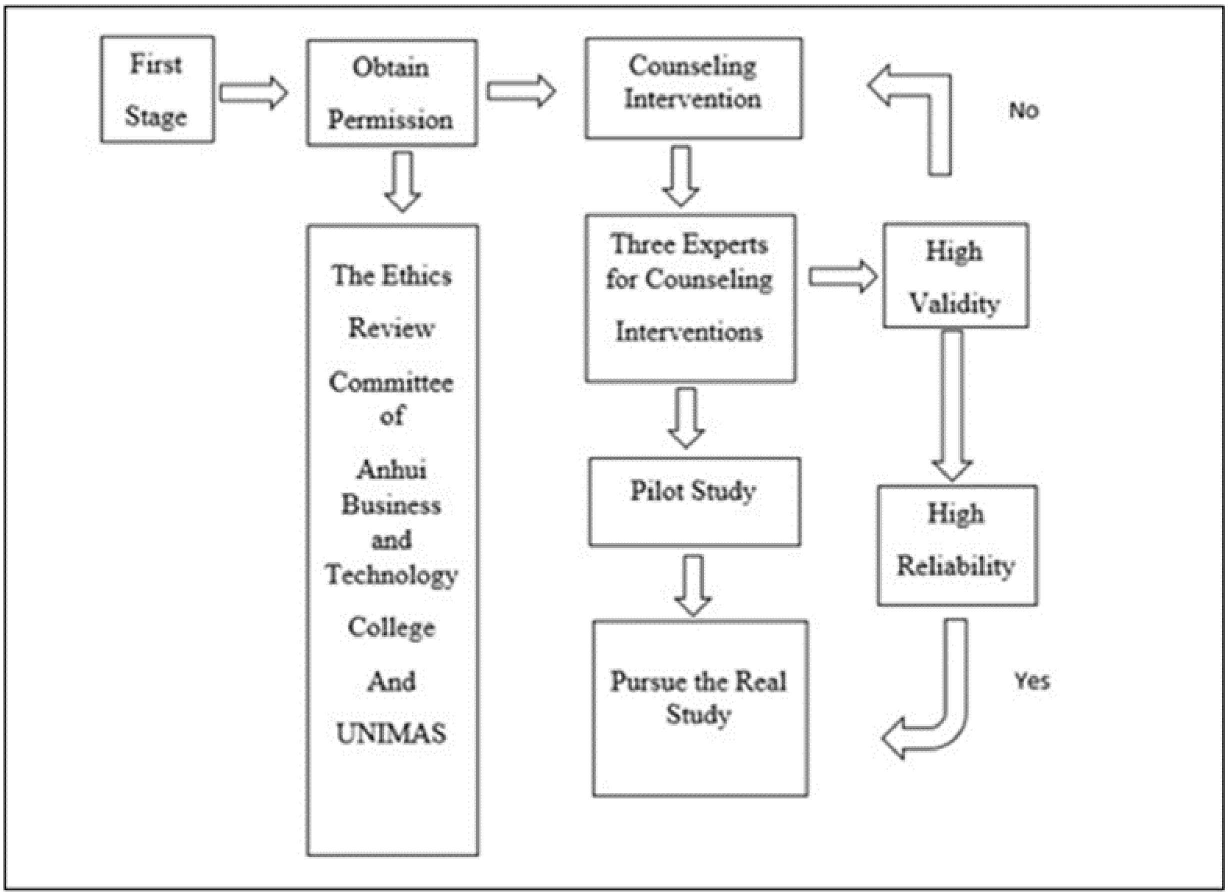

Figure 1: The First Stage of the Chinese Mathematics Resilience Interventions

As illustrated in Figure 1, the first stage involves obtaining approval from AHBTC and UNIMAS, designing the intervention process, and evaluating its effectiveness with input from three experts. A pilot study is then conducted to collect and analyse data, assessing whether the intervention meets the required criteria. If reliability and validity are high, the design is finalized; otherwise, revisions are made.

The second stage involves implementing the teaching intervention using a quasi-experimental research design. Participants are assigned to either an experimental or control group. The experimental group undergoes the intervention through a structured course series, while the control group follows traditional teaching methods. Learning performance is assessed through tests and questionnaires, and the Mathematical Resilience Scale is administered at multiple time points to both groups. Changes in resilience scores over time and differences between groups are analysed to evaluate the validity and effectiveness of the Chinese Mathematics Resilience Interventions.

The study employs the Mathematics Resilience Scale to evaluate the impact of the Chinese Mathematics Resilience Intervention. Data collection involves a validity assessment and expert feedback, while statistical analysis is conducted using SPSS.

In experimental studies involving school students, the field of counselling has established a clear set of ethical guidelines to protect the welfare of research participants. These guidelines are essential to ensure the ethical conduct of research. This study adhered to the following three ethical principles: Participants were school students aged 18 years and above. Written consent was obtained from both the students and the school prior to the initiation of the study. All personal information of participants was kept confidential throughout the duration of the study. In the event that any issues arose concerning the students' well-being or if additional support services were needed, the researchers immediately informed the relevant school authorities to facilitate appropriate action.

4. Results

Khalid et al. (2024) suggest that a panel of three experts is sufficient for module evaluation. In this study, experts were selected based on their professional knowledge, experience in module development, and expertise in educational research.

Three experts have extensive experience in educational intervention. These experts responded promptly via email. Subsequently, UNIMAS's FCSHD sends out an official invitation letter, and the expert responds via email and fills out the expert form.

To assess the validity of the module content, experts used a modified version of Russell’s (1974) Module Content Validity Questionnaire, further refined by Sidek and Jamaludin (2005). This evaluation determined the content validity of the Chinese Mathematics Resilience Interventions. The content validity questionnaire was given to three experts to evaluate the developed modules, while the reliability questionnaire was administered to 20 students to evaluate the reliability of the modules.

The feasibility of the modules was assessed through data validation by three experts specializing in learning modules, instructional design, and learning tools. Validation sheets, structured as feedback forms, were distributed to both experts and students. Following the validation process, test results were analyzed, incorporating evaluations from experts in module content, instructional design, and learning tools, with students serving as test subjects. To assess validity, the study employed Lawshe’s Content Validity Ratio (CVR) formula (Lawshe, 1976):

$$CVR = \frac{n - \frac{N}{2}}{\frac{N}{2}}$$

Here, CVR represents the content validity ratio, where n denotes the number of experts who deem an item essential, and N is the total number of experts. The CVR ranges from -1 to 1, with positive values indicating that experts consider the item essential and negative values suggesting otherwise. An item is typically regarded as valid if its CVR exceeds a predefined threshold.

In this study, all items achieved a CVR of 1.0. Given that the minimum acceptable CVR value with three experts is also 1.0, all items meet the content validity criteria.. Enhancements included incorporating more real-world mathematical problems and tailoring tasks to different proficiency levels, enabling students to encounter challenges and develop resilience in their mathematical learning journey.

The intervention process provides structured curriculum guidance across different academic stages, assisting students in career planning while fostering higher-order thinking skills. However, to better accommodate students with varying learning abilities and enhance inclusivity and engagement, further refinements are needed. First, incorporating tasks with varying levels of difficulty can better address diverse learning needs. Second, introducing open-ended questions can encourage students to articulate their thought processes. Finally, integrating interdisciplinary knowledge and real-world applications into the curriculum can create a more comprehensive and engaging learning experience. These refinements will further optimize the intervention module, ensuring a more inclusive and effective educational framework.

A questionnaire was administered to assess students' responses to the Chinese Mathematics Resilience Interventions module.

In the event that the results reveal less favourable student responses, revisions are made to the module content. A positive response is defined as more than 50% of students providing favorable feedback on at least 70% of the aspects assessed. If this threshold is met, it indicates a positive student response to the Chinese Mathematics Resilience Interventions (Hattie & Timperley, 2007; Polit & Beck, 2006). Student feedback on learning activities was collected through the questionnaire and analyzed using descriptive statistics, with results presented in percentage form.

$$\text{Percentage of Positive Responses(PPR)} = \frac{\text{Number of students with positive responses}}{\text{Total number surveyed}}$$

The percentage of positive feedback in this study is 70.62%.

The reliability of the module was assessed through students' evaluations of the learning objectives. Specifically, the reliability refers to the consistency and stability in achieving the module's goals. In this study, the MRS was developed by the researcher based on the activity objectives, following procedures for reliability assessment outlined by Russell (1974) and Sidek and Jamaludin (2005). The Cronbach’s Alpha coefficient method was employed to evaluate the reliability of the MRS. According to Majid (2009), a reliability coefficient above 0.60 signifies adequate consistency, while values below this threshold suggest a need for improvement.

Table 1: Cronbach Alpha

No.	Theme	Cronbach Alfa
1	The group starts	0.948
2	Value	0.981

3	Struggle	0.985
4	Growth	0.951
5	Resilience	0.975
6	Mathematical resilience	0.988
7	The group ends	0.969

As shown in Table 1, the Cronbach's Alpha values for all module objectives exceed the minimum acceptable threshold of 0.60, indicating high consistency across all themes. The "Mathematical resilience" theme demonstrated the highest reliability, with a coefficient of 0.988, indicating excellent internal consistency. Even the lowest value, 0.948 for the "Group Starts" theme, remains well above the acceptable minimum, further supporting the overall reliability of the module. These findings suggest that t the Chinese Mathematics Resilience Interventions exhibit strong internal consistency and is reliable for its intended use.

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Before the intervention, the study aimed to confirm the absence of significant differences in the dependent variable mean scores between the experimental and control groups at the pretest stage. A one-way analysis of variance (ANOVA) was performed to compare mean differences between the experiment group and control group.

Table 2: One-Way Analysis of Variance (ANOVA) Statistics for Pre-Test Data

Source of Variation	Sum of Squares	DF	Mean Square	F	p
Between Groups	135.2	1	135.2	0.38	0.539
Within Groups	27747.8	78	355.741		
Total	27883	79			

Table 2 presents the one-way ANOVA results for pre-test data, comparing the experimental and control groups before the intervention. The analysis indicates no significant differences between the groups at baseline.

To assess this assumption, Levene's test for homogeneity of variance was performed to evaluate whether variance in quantitative data remained consistent across groups over time. A significant p-value ($p < 0.05$) indicates unequal variances, suggesting variability across groups, while a non-significant p-value ($p > 0.05$) confirms homogeneity. The results are detailed in Table 3.

Table 3: The Variance Homogeneity Analysis Result

Time (Standard Deviation)					
Pre- test	Post-test1	Post-test2	Post-tes3	Retention-test	F
19.29	17.08	15.17	15.94	18.27	2.957

*p<0.05 **p<0.01

The data confirm that the MR variable maintains homogeneity of variance across time points, meeting the assumptions for ANOVA. A two-factor independent samples ANOVA (Table 4) reveals a significant difference in mean scores between the experimental and control groups.

Table 4: The Result of ANOVA Test

Source	Sum of Squares	df	Mean Square	F	p
Time	332.565	4	83.141	1.985	0.096
Experiment	251.222	1	251.222	5.998	0.015*
Experiment × Time	191.315	4	47.829	1.142	0.336

Note： $R^2 = 0.04$ * p<0.05 ** p<0.01

Given the significant main effect of the experiment, post-hoc multiple comparisons were performed (Table 5).

Table 5: Post-hoc Multiple Comparisons

Comparison	Mean Difference	SE	t-value	p-value
1.0 - 2.0	1.585	0.647	2.449	0.015

The intervention has a significant effect on the dependent variable ($p = 0.015$), indicating a clear distinction between the experimental and control groups.

The Shapiro-Wilk test for multivariate normality yielded a W statistic of 0.974, indicating an approximately normal distribution. However, the associated p-value suggests a slight deviation from normality. Given the sample size exceeds 30, and MANOVA is generally robust to violations of multivariate normality, the results remain valid. A repeated measures ANOVA was then conducted to examine changes in the experimental and control groups across time points (pre-test, post-test 1, post-test 2, post-test 3, and retention test). The results are presented in Table 6.

Table 6: Results of Repeated Measures ANOVA

Effect	Sum of Squares (Effect)	Sum of Squares (Error)	df (Effect)	F	Generalized eta-squared
Experiment	2964.802	23476.795	1	9.85	0.026
Time	988.06	89502.83	4	0.861	0.009
Experiment× Time	1101.91	89502.83	4	0.96	0.01
Effect	**Mean Square (Effect)**	**Mean Square (Error)**	**df (Error)**	**p**	**Partial η2**
Experiment	251.223	43.412	78	0.002	0.112
Time	83.141	41.504	312	0.488	0.011
Experiment×Time	47.829	41.504	312	0.43	0.012

As shown in Table 8, neither the main effect of time nor the interaction between intervention and time reached statistical significance. The mean comparisons for time and intervention are illustrated in Figure 2.

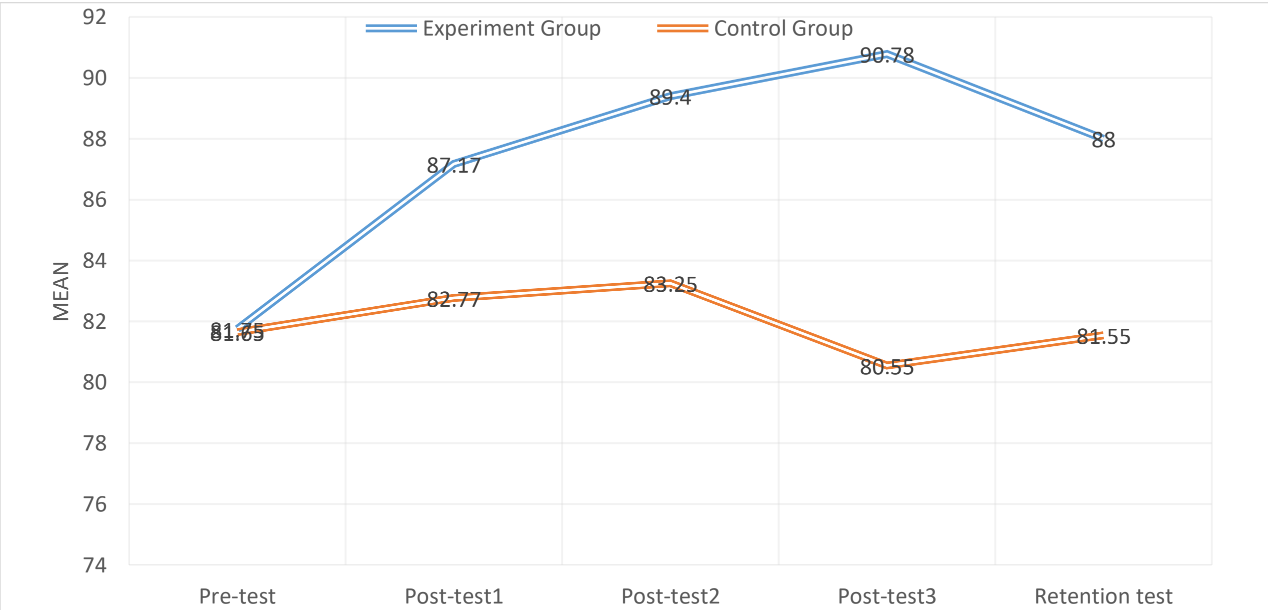

Figure 2: The Comparison of Means for Time and Intervention

Paired t-tests were performed to compare the experimental group's results across testing stages. The data were first processed to compute differences between test pairs, followed by an assessment of normality in the difference values. Given that the sample size was below 50 in all cases, the Shapiro-

Wilk (S-W) test was applied. The results indicate that only the first two comparisons reached statistical significance. Consequently, the Wilcoxon signed-rank test was used for comparisons where the normality assumption was not met, as shown in Table 7.

Table 7: Paired Samples Wilcoxon Analysis Result

Name	Paired Median M (P25, P75)		Difference	p
Pre-test paired with post-test1	61.750 (46.0,84.0)	70.000 (60.0,78.0)	-8.25	0.141
Pre-test paired with post-test2	61.750 (46.0,84.0)	71.000 (58.0,83.0)	-9.25	0.055
Pre-test paired with post-test3	61.750 (46.0,84.0)	70.775 (60.0,80.0)	-9.025	0.055
Pre-test paired with Retention test	61.750 (46.0,84.0)	69.000 (56.0,84.0)	-7.25	0.137
Post-test1 paired with post-test2	70.000 (60.0,78.0)	71.000 (58.0,83.0)	-1	0.527
Post-test1 paired with post-test3	70.000 (60.0,78.0)	70.775 (60.0,80.0)	-0.775	0.619
Post-test1 paired with Retention test	70.000 (60.0,78.0)	69.000 (56.0,84.0)	1	0.773
Post-test2 paired with post-test3	71.000 (58.0,83.0)	70.775 (60.0,80.0)	0.225	0.755
Post-test2 paired with Retention test	71.000 (58.0,83.0)	69.000 (56.0,84.0)	2	0.591
Post-test3 paired with Retention test	70.775(60.0,80.0)	69.000(56.0,84.0)	1.775	0.638

5. Discussion

The one-way ANOVA results for the pre-test data indicate no significant differences between the experimental and control groups prior to the intervention. A two-factor ANOVA was conducted to examine the effects of Experiment and Time on the Value variable. The analysis revealed a significant main effect of Experiment, suggesting that the intervention had a differential impact on mathematics resilience (MR). However, the effect of Time was not significant, nor was the interaction between Time and Experiment. These findings indicate that the intervention's effect remained stable across time points.

Post-hoc multiple comparisons further confirmed the intervention's significant effect on the dependent variable (p = 0.015), demonstrating a marked difference between the experimental and control groups. A MANOVA was then performed to assess the influence of multiple dependent variables. The Welch ANOVA results corroborated these findings, confirming significant differences between the experimental and control groups for the Value variable. A repeated measures ANOVA further indicated a highly significant intercept effect (F = 0.982), with a substantial proportion of variance attributed to baseline differences. The experiment effect was statistically significant with a medium effect size, as reflected by the partial eta-squared value. According to Cohen (2013), a medium effect size corresponds to an eta-squared value of approximately 0.06. However, the effect of Time did not reach statistical significance at the 5% level, though the effect size suggested a minor influence. The interaction between Experiment and Time was also non-significant, indicating that the intervention's effect did not fluctuate substantially across time points.

Paired Wilcoxon signed-rank tests further examined within-group differences. Significant improvements were observed between the pre-test and post-test 2, as well as between the pre-test and post-test 3, suggesting a mid-term impact of the intervention. However, comparisons between the pre-test and post-test 1, as well as the retention test, were not statistically significant, indicating limited immediate and long-term effects. Comparisons among post-tests and the retention test also failed to reach significance, suggesting that performance gains stabilized over time.

These findings advance two theoretical propositions: Mathematical resilience operates as a dynamic system with bidirectional cognition-affect pathways. Effective interventions must employ ecological congruence between cultural learning scripts and regulatory demands. While establishing proof-of-concept for the Chinese Mathematics Resilience Interventions' transportability, critical questions persist regarding dosage-response curves and developmental sensitive periods. Future multi-site replication studies employing mixed-methods designs could elucidate the cultural neuroscience underpinnings of observed effects, potentially revolutionizing mathematics education through biologically-informed, culturally-attuned intervention frameworks.

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