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The Chinese adaptation of the mathematical resilience scale among high school students: Validity and reliability study

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Abstract: Mathematical resilience (MR) is a critical learning attitude that enables students to overcome challenges in mathematics. However, there is a lack of validated instruments to assess MR in Chinese high schools. This study aimed to adapt the internationally developed Mathematical Resilience Scale (MRS) for Chinese high school students and evaluate its reliability and validity. Using a quantitative research design, the study conducted three rounds of confirmatory factor analysis (CFA) to examine the three-factor structure (value, struggle, and growth). The first two rounds revealed low correlations between factors and weak loadings on resilience. After eliminating translation issues, removing items (V7, S5), and adapting the reverse-scored items to make them positively scored, the study demonstrated good structural, discriminant, and convergent validity. The Cronbach's alpha coefficients were 0.891 (value), 0.892 (struggle), 0.910 (growth), and 0.927 (overall scale), while McDonald's omega values were 0.891 (value), 0.890 (struggle), 0.909 (growth), and 0.922 (overall scale). These findings indicate that the adapted MRS is a reliable and valid tool for assessing MR among Chinese high school students. This study provides a practical instrument for educators to identify and support students with low MR, ultimately enhancing their mathematical learning outcomes and reducing math anxiety.
Keywords: *Mathematical resilience, Reliability, Scale, Validity.*

1. Introduction

Mathematics, as a crucial field in students' academic development, is often regarded as one of the most challenging subjects. Many students experience anxiety and frustration during their mathematical learning journey, and these emotional barriers significantly hinder their progress in mathematics [1, 2]. To address this issue, Johnston-Wilder and Lee [3] introduced the concept of "Mathematical Resilience" (MR). Mathematical resilience refers to students' ability to overcome setbacks, maintain positive emotions, and demonstrate a persistent attitude towards learning mathematics [3]. This resilience enables students to sustain their engagement and progress in mathematics while maintaining confidence throughout the learning process. Conversely, when students lack mathematical resilience, both the process and outcomes of learning mathematics are negatively affected [3, 4].

As of October 2024, searches using the term "mathematical resilience" in databases such as Google, ERIC, Web of Science, and Scopus show that there were only sporadic publications before 2013. However, in recent years, there has been a significant increase in the number of studies, spanning nearly 20 countries. In these countries, mathematical resilience has been proven to be an effective framework for alleviating math anxiety [5-10].

In China, educational reform emphasizes a "student-centered" approach, focusing on students' mental health and holistic development. However, math anxiety is prevalent in China and severely impacts students' mental well-being [1, 11]. Mathematical resilience offers Chinese educators and researchers a novel perspective to explore effective interventions, enhance students' psychological

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resilience in math learning, mitigate math anxiety, and foster their ability to persist and stay motivated when facing mathematical challenges.

The Mathematical Resilience Scale (MRS) is a tool for measuring changes in MR. It provides a means to understand students' levels of mathematical resilience and track the effectiveness of interventions, making it an indispensable component in many empirical studies. Countries such as the United States, Turkey, and Nigeria have localized the original MRS developed in the United Kingdom, making minor adjustments to the items while preserving its overall cross-cultural adaptability. These cross-cultural studies have shown that the MRS has the potential to become a global tool for assessing and promoting MR. However, the MRS has not yet been adapted for use among high school students in China, highlighting the need for research on its localization in this context.

The primary research question of this study is: What is the reliability and validity of the MRS among high school students in China?

2. Theoretical Foundation

2.1. Research Framework

To mitigate students' math anxiety, Johnston-Wilder and Lee [3]. Johnston-Wilder, et al. [12] explained how Self-Determination Theory (SDT) serves as a framework for exploring the causes of mathematics anxiety and proposed a theoretical framework for developing MR within the SDT framework to address this issue [12]. SDT is based on the premise that meeting basic psychological needs promotes well-being, ensures psychological safety, and prevents psychological harm [13]. The frustration or deprivation of these needs can lead to severe harm, including the emergence of anxiety [13]. Humans have three fundamental psychological needs: autonomy, competence, and relatedness [13]. Autonomy refers to the sense of control over one's actions, feeling that one can choose and decide freely without external coercion or control. Competence reflects the experience of effectively addressing challenges, completing tasks, and achieving success. Relatedness involves the need to feel a sense of belonging, acceptance, and care in interpersonal interactions.

The framework of MR is closely related to SDT [14]. The MR framework includes four attributes, three of which correspond to SDT's basic psychological needs: personal value in mathematics (autonomy), growth mindset (competence), and community (relatedness). The fourth attribute, struggle, recognizes the necessity of perseverance in mathematics learning, even in anxiety-inducing environments. While this attribute is less explicitly related to SDT, it aligns with theories of human agency, which emphasize individuals' ability to evaluate and control their thoughts, motivations, and behaviors [15].

Personal value in mathematics refers to the belief in the importance and utility of mathematics, reflecting students' recognition of its value [16]. This value encompasses emotional, practical, and intellectual aspects, signifying the meaningfulness of mathematics to an individual [16]. In mathematics, a growth mindset refers to the belief that mathematical skills can be developed through effort and perseverance, challenging the fixed-trait notion of mathematical ability [17]. Community, in the context of mathematics, refers to a supportive network that fosters mathematics learning and resilience. This includes teachers, peers, family members, and any group providing encouragement, resources, and a collaborative environment for mathematical growth [18]. Struggle involves efforts to understand challenging concepts and persist in addressing difficulties. Facing these challenges actively fosters deeper understanding and solid learning [16] making struggle an indispensable part of cultivating MR [12, 14]. The research framework in this study builds on previous studies, where Kooken, et al. [16] developed the MRS into three dimensions: personal value, struggle, and growth mindset, excluding the community dimension [14].

2.2. *Literature Review*

The original Mathematical Resilience Scale (MRS) was developed in the UK [16]. The researchers designed the scale items using a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). The scale underwent a rigorous content validity process, starting with 46 items reduced to 33 through a panel of nine experts who evaluated category matching, relevance, and item wording. Subsequently, the scale went through three phases of pilot testing, including two Exploratory Factor Analyses (EFA) and one Confirmatory Factor Analysis (CFA) in three different UK samples. The final version, which originally hypothesized four factors (values, struggle, growth, and resilience), was refined into a three-factor structure: values, struggle, and growth, comprising 24 items, with the last six items reverse-scored. Cross-cultural adaptability is a key step to ensure the applicability and relevance of MRS in different cultural contexts, making cross-cultural validation essential.

Researchers in several countries have localized the original MRS. In Gürefe and Akçakin [19]aimed to validate the MRS for Turkish undergraduate students [19]. Instead of a literal translation, cultural adaptability was considered when translating the original English version into Turkish. After initial translation and back-translation, a series of statistical analyses were conducted to assess the factor structure, reliability, and validity of the scale. Confirmatory Factor Analysis (CFA) validated the original three-factor structure of MRS, including values, struggle, and growth. The reliability coefficients for these factors and the overall scale were high, indicating that the Turkish version of MRS is reliable. The study concluded that the Turkish-adapted MRS, consisting of 19 items, effectively and reliably measures undergraduate students' MR. It also explored challenges and considerations in cross-cultural scale adaptation, such as linguistic nuances, cultural norms, and educational practices.

In addition, Awofala [20] revalidated the original MRS using Nigerian samples. The study assessed the scale's structural fit and reliability using CFA and Cronbach's alpha [20]. The results demonstrated that the scale is a valid method for measuring MR among Nigerian high school students, with statistically significant relationships between MR dimensions and mathematics achievement. The three dimensions of MR contributed 48.3% to the prediction of mathematics achievement, showing statistical significance. This study contributed to the field of mathematics education by providing evidence that the MRS is a valid tool for assessing MR among students in southwestern Nigeria. Lovelace [21] adapted the original MRS for the first time for American high school students, showing that the scale was successfully adapted to the American context, with three items removed from the original 24 [21]. However, the study suggested further investigation into the dimension of struggle, examining students' attitudes toward accessing resources and the productive role of struggle in learning, to improve the scale items.

In recent two year. Atahan and Uyangor [22] developed a scale included four sub-dimensions: value, struggle, growth, and culture. Firstly, revised by language experts and subject-specific scholars, the original 103 potential items were refined into a draft scale consisting of 26 items. Then both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were conducted. The results of the EFA revealed that the scale consists of 14 items, which are organized into the above four sub-dimensions: value, struggle, growth and culture. These factors collectively explained 57.667% of the total variance. In terms of reliability, the Cronbach's alpha coefficient was calculated to be .704. Furthermore, the CFA confirmed the four-factor structure of the scale. These findings demonstrate that the scale is both valid and reliable for measuring students' mathematical resilience. Wei, et al. [23] examined how reliable the mathematical resilience Scale was among Chinese upper elementary school students. The test of modified item-related total score coefficients showed that the modified item-related total score coefficients of item 16 (0.273) and item18 (0.257) were less than 0.400, and were therefore given to be deleted. Item 7 endorses the view that mathematical ability is solidified, a view that is contrary to the growth view of ability and presents a significant negative loading on the growth factor. It was therefore given for deletion, and 3 of the final 24 items were deleted. However, it was also found that the correlations between value and struggle, value and growth, and struggle and growth were 0.634, 0.244, and 0.137 respectively, and there are no analysis about three-factor loading in secondordert hree-factor structure, and according to Fornell and Larcker [24] suggestion, inter-factor correlations usually need to be moderate or above (> 0.3) to support the construction of a higher dimensional model. Therefore, the ability of the three factors to constitute resilience deserves further reflection and its adaptation among older young students needs to be further tested. Xia and Madihie [25] adopted exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), the four-factor scale (value, struggle, growth, and resilience) developed by Kooken and Costelnock [26] was tested among university students. Ultimately, items G3, G4, G5, G6, and G7 were deleted, resulting in a scale with good reliability and validity. However, 'growth' underwent significant item reduction, leaving only three items, while other dimensions retained eight or nine items. If the number of items in a certain dimension is significantly fewer than those in other dimensions, the overall scale score will be dominated by the dimensions with more items, leading to an imbalance in the contributions of each dimension. Kooken and Costelnock [26] conducted a confirmatory factor analysis (CFA) on the sample data using a 24-item Mathematical Resilience Scale with three dimensions: value, struggle and growth. The results showed that the model had poor fit for 'struggle' and 'growth', while the Value factor demonstrated strong psychometric properties. The model fit indices indicated room for improvement: χ^2 (272, N=189) = 614.04, $p < .01$; RMSEA = 0.08 (90% CI = [0.07, 0.09]), CFI = 0.67, TLI = 0.64. Subsequently, the researchers employed an exploratory approach to identify a model that better fit the sample data and excluded variables related to 'value'. Through CFA and analysis of item correlations, they ultimately identified a two-factor structure with good model fit and internal consistency reliability. The factor loadings were stable, ranging from 0.350 to 0.739. The model fit reached an acceptable level: χ^2 (103, N=189) = 170.14, $p < .001$, RMSEA = 0.059 (90% CI = [0.043, 0.074]), CFI = 0.905, TLI = 0.890.

The development of the MRS was a groundbreaking milestone in mathematical resilience research, while the localization studies in other countries further proved the scale's validity. Overall, the development and cross-cultural adaptability studies of the MRS reveal its potential to become a global tool for assessing and promoting MR. These detailed descriptions of development and adaptations enrich the knowledge system of cross-cultural research methods and provide a framework for future development and adaptation of educational psychology scales.

3. Research Methods

3.1. Research Participants

The study involved three samples, as detailed below:

Sample 1: 594 high school students from Nanchang, Yichun, and Jiujiang in Jiangxi Province, including students from grades 10, 11, and 12. Sample 2: 642 undergraduate and associate degree students majoring in elementary education, English education, and STEM fields. These students were from Nanchang, Henan, Wuhan, Yichun, and Fuzhou, including students in their first, second, and third years. Sample 3: 360 associate degree students in their first and second years, majoring in mathematics education from the Yichun region. The details are shown in Table 1. Sample 1 was used to test the validity of the localized Chinese version of the Mathematical Resilience Scale (MRS). Sample 2 was used for further validation of the localized Chinese MRS. Sample 3 was used to assess the reliability and validity of the revised Chinese version of the MRS.

Table 1.
population distribution for each sample.

Trait	The first sampling	The second sampling	The third sampling
Participants	Grade one, senior two, senior three students	First, sophomore, and junior students in primary education, English education and STEM	Grade one, senior three students
Area	Yichun, Jiujiang, Nanchang	Nanchang, Henan, Wuhan, Yichun, Fuzhou	Yichun
Number	594	642	360

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3.2. Research Instruments

In this study, the original 24-item Mathematical Resilience Scale was used for the first two rounds of data collection. The instrument underwent rigorous authorization, translation, and back-translation procedures:

Permission from the Scale Developer**:** We contacted Janice Kooken, the original developer of the MRS, via email to obtain permission to adapt the scale into Chinese.

Preliminary Translation**:** The English version of the MRS items was independently translated by mathematics experts and master's students specializing in translation.

Comparison and Standardization**:** The two translations were compared, and a unified Chinese version of the MRS (draft version) was created through discussion.

Pilot Study and Revision: A group of 10 students was selected to assess the comprehensibility of the initial Chinese version of the MRS. Ambiguous expressions were identified and revised, resulting in the second draft.

Back-Translation and Finalization**:** A linguistics expert back-translated the second Chinese draft of the MRS into English.

For the third round of data collection, a linguistics expert modified the 24-item MRS used in the previous rounds. Specifically, the six items in the "Growth" dimension that had reverse scoring were linguistically adapted to avoid reverse scoring. The adaptation retained the original meaning of the items while ensuring that higher scores consistently indicated greater resilience. For example:

> The original item, "If someone is not a math person, they won't be able to learn much math" was rephrased as "If someone is not a math person, they can still learn a lot of math."
>
> Another item, " If someone is not good at math, there is nothing that can be done to change that," was changed to "If someone is not good at math, they can change it through hard work."

For items with significant translation differences, the original translators and the linguistics expert discussed and finalized the Chinese version of the MRS.

During the translation process, Hambleton and De Jong [27] test adaptation method was used to achieve linguistic equivalence. This method prioritizes cultural adaptation over literal translation, ensuring equivalence between the original and translated items while adjusting the items for compatibility with Chinese culture. The goal was to ensure precision and clarity, involving mathematics experts and professional translators in the initial translation. Students' feedback was incorporated to improve the comprehensibility of the Chinese version. The back-translation and subsequent discussions ensured linguistic equivalence between the final Chinese version and the original English version of the MRS.

3.3. Data Collection and Processing

This study collected questionnaire data in three rounds:

> First Round: Data were collected from high school students. Since high school students were not allowed to bring mobile phones into the classroom, paper-based questionnaires were distributed and collected by the mathematics teachers of the respective classes.
>
> Second Round: Data were collected from university students. As university students were allowed to bring mobile phones into the classroom, questionnaires were distributed and collected via the Wenjuanxing (Questionnaire Star) platform.
>
> Third Round: Data were again collected from high school students. Paper-based questionnaires were distributed and collected by the mathematics teachers of the respective classes.

During the data processing phase, the psychometric properties of the scale were assessed using AMOS 23.0. Structural validity and reliability were examined, and discriminant validity and convergent validity were calculated. Exploratory Factor Analysis (EFA) was not employed in this study, as the dimensional structure of the original scale had already been validated. Instead, the study began with Confirmatory Factor Analysis (CFA) to determine the dimensional structure and item fit of the scale within the Chinese cultural context. Additionally, Cronbach's Alpha and McDonald's Omega coefficients were used to assess the internal consistency of the entire scale and its subfactors. Item-total correlations were also calculated to further validate internal consistency.

4. Research Process and Results

This study utilized Confirmatory Factor Analysis (CFA) to evaluate the applicability of the original MRS dimensions in the Chinese cultural context, conducting three rounds of CFA. In this context, V, S, and G denote 'value', 'struggle', and 'growth', respectively. Validity analysis was conducted based on the outcomes of the third CFA, which was subsequently followed by reliability analysis.

4.1. Results of the First CFA

The factor loading for G1 was 0.34, indicating insufficient information capacity. Brown [28] discussed the application of CFA and suggested that factor loadings should exceed 0.5 [28]. Therefore, the G1 item was considered for removal. The correlation coefficients between dimensions were as follows: 'value' and 'struggle' = 0.65, 'struggle' and 'growth' = 0.11, and 'value' and 'growth' = 0.18. The latter two coefficients were very low. If the correlations among dimensions are insufficient to support a higher-order factor structure, deriving a higher-order model should be avoided [28]. This indicates that the items for 'value' may not constitute a measurement dimension or items for resilience. In the second-order structure: The factor loading for 'value' was 1.04, 'struggle' was 0.62, and 'growth' was 0.17. The factor loading for 'growth' was below 0.5, further suggesting that 'growth' or its items might not constitute valid measurement dimensions or items for resilience.

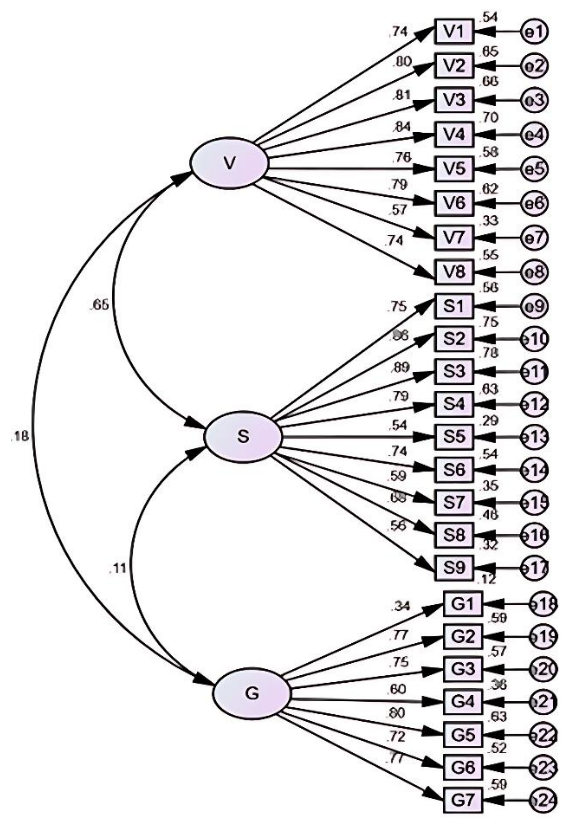

Figure 1.
Initial Model of First-Order Three-Factor Structure.

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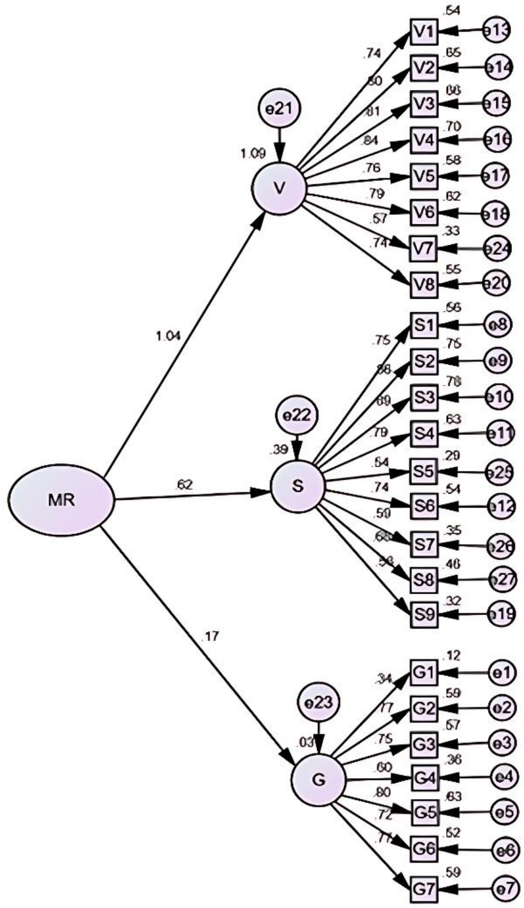

Figure 2.
Initial Model of Second-Order Three-Factor Structure.

4.2. Results of the Second CFA

To further explore whether 'growth' or its items could constitute a dimension or items for measuring resilience, the study conducted a second CFA after changing the sample and removing item G1. The results showed: the correlation coefficient between value and struggle was 0.48, between struggle and growth was 0.13, and between value and growth was 0.07. In the second-order structure, the factor loadings were as follows: value = 0.98, struggle = 0.49, and growth = 0.14. These findings further confirmed that 'growth' or its items could not constitute a valid dimension or items for measuring resilience.

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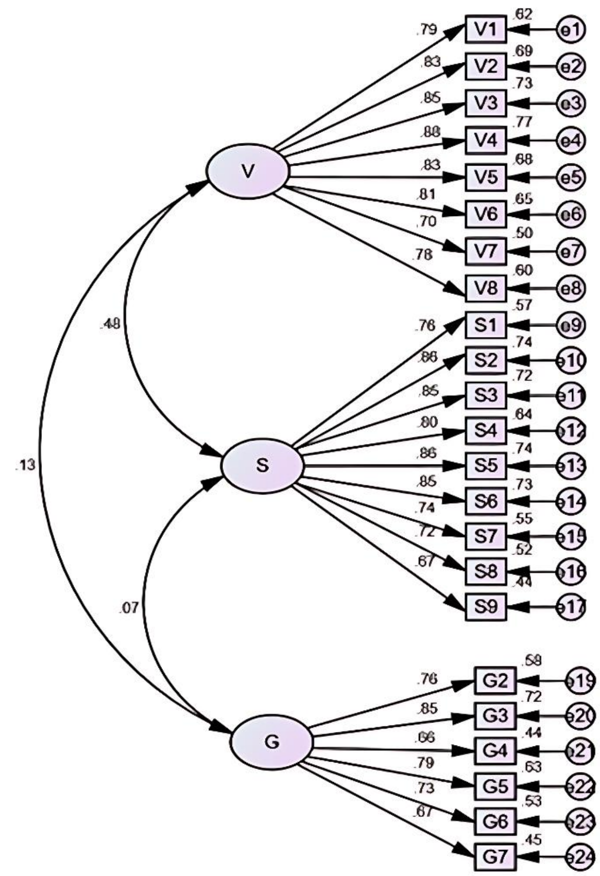

Figure 3.
Model of First-Order Three-Factor Structure.

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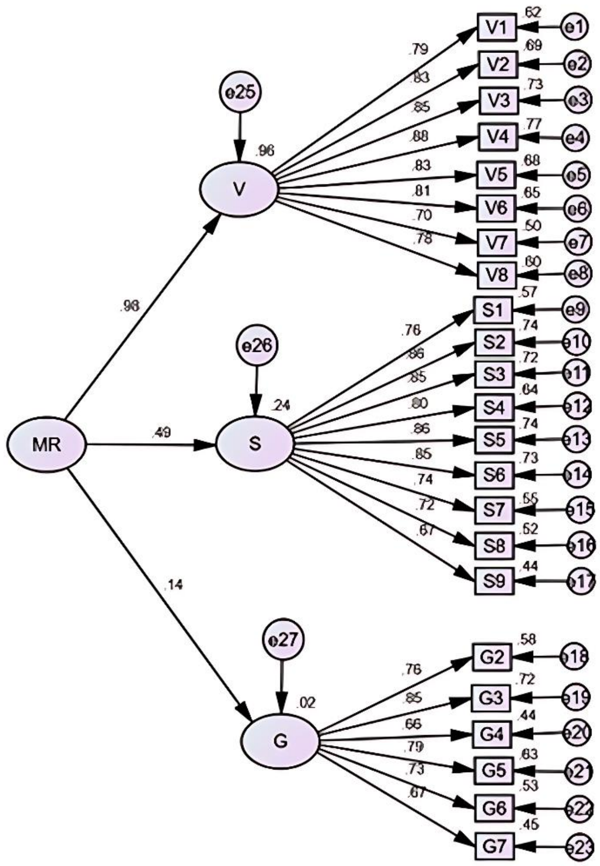

Figure 4.
Model of Second-Order Three-Factor Structure.

4.3. Results of the Third CFA

Swain, et al. [29] discussed the issue of incorrect responses caused by reverse-scored items and found that reverse scoring might confuse respondents, thereby affecting the validity of measurement results. Sonderen, et al. [30] suggested that reverse scoring not only failed to significantly improve the quality of the scale but could also introduce systematic bias due to misunderstanding or lack of attention. Podsakoff, et al. [31] highlighted that reverse-scored items could lead to common method bias, thus impacting correlations and factor loadings. Wang [32] found positive and negative formulations have implications of either a positive or negative nature. Different formulations can produce different effects, and the results of these effects may vary depending on cultural differences. In this round of the study, a three-dimensional revised scale was used to collect and analyze data, in which 'growth' was positively scored. The CFA results showed that the correlation coefficients were as follows: value and struggle = 0.56, struggle and growth = 0.52, and value and growth = 0.52. These values indicate the possibility of a higher-order structure among the factors. Among the 24 items, the factor loadings of S5 was 0.33, demonstrating that the item should be deleted. As showed in figure 5. After deleting S5, the factor loading of V7 in the first-order three-factor structure was below 0.5. As showed in figure 6. After deleting V7, among the 22 items, the factor loading was above 0.6. The items had good information-carrying capacity and effectively explained their respective factors. As showed in figure 7. In the second-order structure: The factor loading for 'value' was 0.74, 'struggle' was 0.73, and 'growth' was 0.71. they were all above 0.7, further suggesting that 'value', 'struggle' and 'growth' constitute valid measurement dimensions for mathematical resilience. As showed in figure 7. After removing V7 and S5, the overall fit indices improved, indicating that the adjusted model better reflects the characteristics of the actual data, as shown in Table 2.

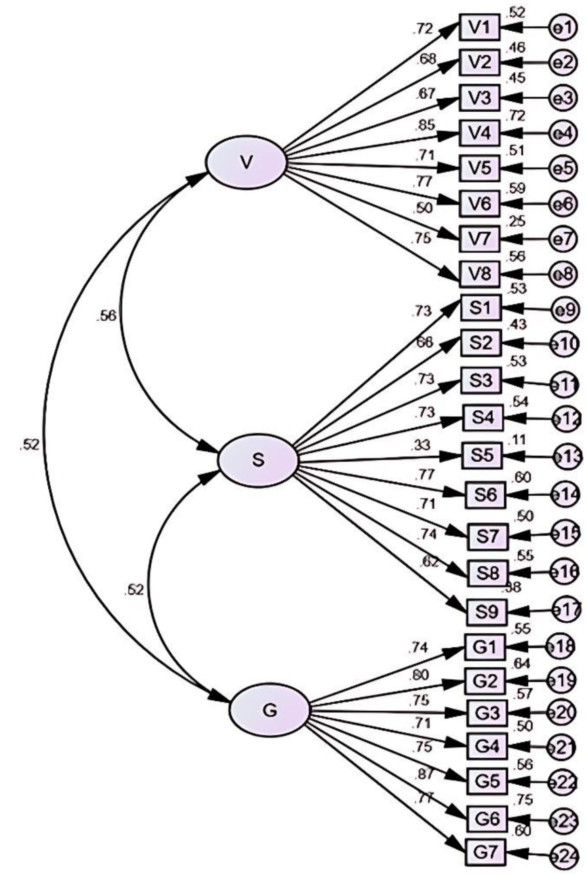

Figure 5.
Model of First-Order Three-Factor Structure

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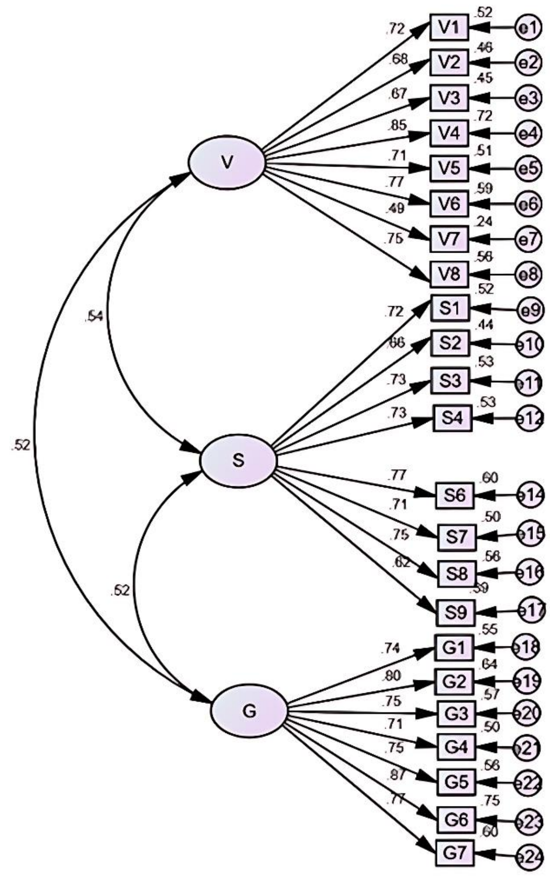

Figure 6.
Model of First-Order Three-Factor Structure

Table 2.
Comparison of Fit Indices for the First-Order Three-Factor Mode.

Models	Description	χ2/df	IFI	TLI	CFI	RMSEA	RMSEA 【LO90-HI90】	AIC	BCC
Model1	All items	3.91	0.854	0.837	0.853	0.090	0.084—0.096	1123.51	1134.74
Model2	Remove S2	2.740	0.914	0.904	0.914	0.070	0.063—0.076	765.92	776.24
Model3	Remove S2&V7	2.83	0.916	0.905	0.916	0.071	0.065-0.078	720.99	730.43

In the second-order three-factor structure, the factor loadings were: value = 0.74, struggle = 0.73, and growth = 0.71, which indicates that the factors had strong information-carrying capacity and effectively explained the higher-order resilience structure. As showed in figure 8.

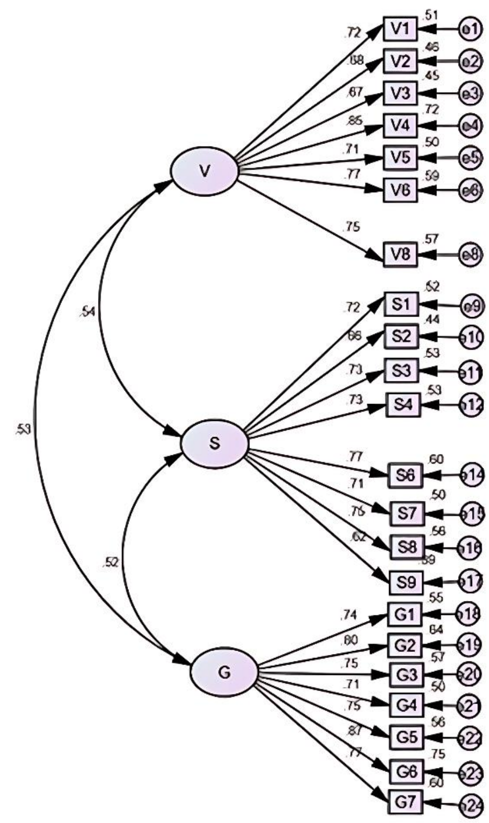

Figure 7.
Model of First-Order Three-Factor Structure.

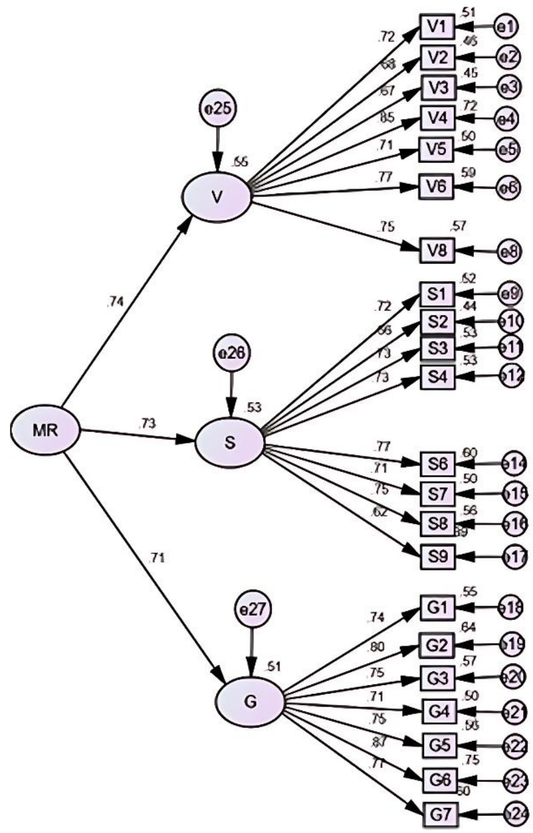

Figure 8.
Model of Second-Order Three-Factor Structure.

Based on the factor loadings, The Average Variance Extracted (AVE) values for each dimension are as follows: value (0.54), struggle (0.51), and growth (0.60). The square roots of AVE values for each dimension are as follows: value (0.74), struggle (0.72), and growth (0.77). The correlation coefficients between value, struggle, and growth and the square roots of their AVEs are listed in Table 3. Since the AVE is greater than 0.5, this indicates good convergent validity for both first-order and second-order factors. Furthermore, since the correlation coefficients between value, struggle, and growth are all smaller than the square root of their AVEs, this indicates good discriminant validity among these factors.

Table 3.
Value, struggle and growth correlation and AVE square root.

	value	**struggle**	**growth**
value	0.74		
struggle	0.54***	0.72	
growth	0.53***	0.52***	0.77

Note: The diagonal line is the AVE square root of each latent variable

4.4 Reliability Analysis

The reliability of the scale and its factors was assessed using Cronbach's alpha and McDonald's omega coefficients. The internal consistency values, as measured by Cronbach's alpha, were 0.891 for ‘value’, 0.892 for ‘struggle’, and 0.910 for the ‘growth’. For the overall scale, which includes the three factors (value, struggle, and growth), the Cronbach's alpha value was 0.927. Similarly, the McDonald's omega values were 0.891 for ‘value’, 0.890 for ‘struggle’, and 0.909 for ‘growth’r. The overall scale, considering the three factors, had a McDonald's omega value of 0.922. as shown in Table 4. Both Cronbach's alpha and McDonald's omega coefficients are greater than 0.7. Therefore, the scale and its factors have sufficient reliability.

Table 4.
The reliability coefficient of the scale.

Variable	Cronbach's α	Mcdonald's Omega
mathematical resilience	0.927	0.922
value	0.891	0.891
struggle	0.892	0.890
growth	0.910	0.909

The correlations between the items and the total score are also significant, as shown in Table 5, further confirming that the scale has adequate reliability.

Table 5.
Correlation between items and the total score.

item	V1	V2	V3	V4	V5	V6	V8	S1	S2	S3	S4
Correlation	0.606 ***	0.615 ***	0.574 ***	0.693 ***	0.639 ***	0.666 ***	0.644 ***	0.663 ***	0.515 ***	0.644 ***	0.651***
item	S6	S7	S8	S9	G1	G2	G3	G4	G5	G6	G7
Correlation	0.637 ***	0.585 ***	0.618 ***	0.518 ***	0.600 ***	0.6815 ***	0.633 ***	0.590***	0.644 ***	0.664 ***	0.631 ***

Note : ***: $p < .001$

5. Discussion and Research Conclusion

This study adapted the Mathematical Resilience Scale (MRS) developed by Kooken, et al. [16] into Chinese and tested its validity and reliability. To achieve linguistic equivalence, the scale was translated from English to Chinese based on the opinions of language and mathematics experts. The validity and reliability were tested through structural validity, discriminant validity, and convergent validity for validity assessment, while internal consistency coefficients were used for reliability evaluation.

Confirmatory factor analysis (CFA) was conducted to verify the structural validity of the scale. In different research groups, it was found that the correlations between'value''struggle'and'growth' were too small, and the loading factor of growth was too low, while the value loading factor was too high. When investigating potential issues such as translation and reverse-scored items, it was discovered that reverse scoring was the cause of these problems. In the third CFA, the reverse-scored items for 'growth' were adapted to eliminate reverse scoring (i.e., higher scores indicating greater resilience), the results were more appropriate, for example, the correlations between factors are moderate. The model fit indices of the CFA showed an RMSEA was 0.071, $\chi 2/df$ was 2.83, IFI was 0.916, TFI was 0.905, and CFI was 0.916 after deleting S5 and V7, indicating that the model was acceptable. Other indices, such as AIC, BCC, BIC, and CAIC, also decreased, compared with the models with S5 and V7. Thus, the modified model removing S5 and V7 performed better than the initial model. In the adapted scale, all 22 items without reverse scoring had good factor loadings, indicating that they carried sufficient information. The factor loadings for 'value', 'struggle', and 'growth' were also good, and the correlations between these factors were adequate. Compared with previous studies [16, 19, 23] the results of this study showed better model fit performance.

The reliability of the scale and its factors was evaluated using Cronbach's Alpha and McDonald's Omega coefficients. The Cronbach's Alpha internal consistency coefficients were 0.891 for value, 0.892 for struggle, 0.910 for growth, and 0.927 for the overall scale. The McDonald's Omega reliability values were 0.891 for value, 0.890 for struggle, 0.909 for growth, and 0.922 for the overall scale. These values indicate high reliability for the scale and its factors. Compared with previous studies [16, 19] this study demonstrated that the non-reversed scale has better reliability. Based on these results, it is worth exploring whether non-reversed scoring is more suitable for other countries.

All results from this study suggest that the adapted scale is an effective and reliable measurement tool for assessing high school students' mathematical resilience. To our knowledge, there is no existing research on mathematical resilience among high school students in the Chinese culture, so this adaptation will contribute to the current body of knowledge. The scale can be used to distinguish students who continue to study mathematics despite facing challenges and difficulties. However, there are some limitations in the generalizability of the study's results. First, the third CFA sample in this study came from one region and did not involve younger student groups in China, and only included 360 students in Grade 10 and Grade three, limiting the generalizability of the results. Therefore, we recommend restricting the applicability of the scale to students in high schools. Second, in this study, mathematical resilience was treated as a static phenomenon because it was only assessed in the measurement. This approach didn't reflect the dynamic complexity of MR. Mathematical knowledge is essential from early childhood [33]. Therefore, future studies should evaluate the validity and reliability of this scale at other learning stage. Furthermore, longitudinal research should be conducted to examine the relationship between mathematical resilience (measured by characteristics such as growth, struggle, and value) and teaching strategies, to better understand the relationship between MR and academic performance, as well as how related factors influence mathematical resilience develops. Although not addressed in this study, future research should also test the measurement invariance of the MRS across gender differences, as gender is an important variable in mathematics education.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Institutional Review Board Statement

This study involves human participants and has been designed and conducted in accordance with the ethical principles of the Declaration of Helsinki. Prior to the commencement of the research, the study protocol was reviewed and approved by the Institutional Review Board. All participants provided informed consent voluntarily after being fully informed, and their privacy and data confidentiality were ensured throughout the research process.

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