





Developing and validating a multidimensional mathematics persistence scale: An exploratory and confirmatory factor analysis approach

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ABSTRACT

This study addresses the need for a reliable instrument to measure student persistence in mathematics education by developing and validating the Mathematics Multidimensional Persistence Scale (MMPS). The MMPS was adapted from the existing Multidimensional Persistence Scale through translation and expert review, resulting in a 22-item scale that includes newly developed items to better capture persistence in the context of mathematics learning. The scale was administered to 438 high school students from three schools in Manggarai, East Nusa Tenggara, Indonesia. Exploratory Factor Analysis revealed four factors: Strategic Persistence in Mathematics, Math Avoidance Due to Difficulty, Effortful Persistence Despite Math Anxiety, and Inappropriate Persistence. Confirmatory Factor Analysis supported a good model fit (CFI = 0.924, TLI = 0.903, RMSEA = 0.047), indicating the scale's validity. These results provide a solid foundation for evaluating mathematics persistence and offer educators practical tools to support student engagement. Future research should examine the long-term impact of MMPS-informed interventions on student outcomes.

Keywords: mathematics education, student persistence, scale development, factor analysis

INTRODUCTION

Persistence, the ability to keep going with a behavior or activity to reach a goal even in the face of challenges or prolonged duration (Lufi & Cohen, 1987; Serpell et al., 2009), is starting to become one of the highlights in educational research (Drake et al., 2014; Edwards & Beattie, 2016; Garland et al., 2011; Israel-Fishelson & Hershkovitz, 2019, 2020; Palacios-Abad, 2021) but has not been so popularly studied directly (DiNapoli, 2023; Shechtman et al., 2018). Persistence is often measured as an outcome of other variables that are the main focus of researchers, such as self-efficacy (Jacobs et al., 1984; Multon et al., 1991) and students' affective experiences relative to working on difficult tasks (Tulis & Fulmer, 2013; Vollmeyer & Rheinberg, 2000). However, specifically, research conducted by the World Economic Forum Project (2020) emphasizes that education in the digital era requires students to have skills such as persistence, critical thinking, problem-solving, collaboration, and curiosity, not just in math, science, languages, and arts. Among these, persistence is particularly crucial, as learning with understanding is a marathon that demands sustained effort and resilience in the face of setbacks and challenges (DiNapoli, 2023).

The significance of persistence is highlighted by research conducted through meta-analysis aimed at uncovering critical 21st-century skills in primary and secondary education (see Figure 1), which references the frameworks of the European Skills, Competences, Qualifications, and Occupations (ESCO). Additionally, 21st-century skills extend beyond foundational literacies (literacy, numeracy, scientific literacy, ICT literacy, financial literacy, cultural and civic literacy) and competencies (critical thinking/problem solving, creativity, communication, and collaboration) to include character qualities (curiosity, initiative, persistence/grit, adaptability, leadership, social and cultural awareness) (World Economic Forum Project, 2020). Persistence, as a character quality, is the effort to help children learn to overcome obstacles by allowing them to fail in ways that match their temperament. This approach recognizes that persistence involves both effort and emotional regulation, tailored to individual differences.

In the context of education, persistence is also one of the 9 attitudes and skills needed in the 21st century, according to the OECD Learning Compass 2030, in addition to reflection, collaboration, and co-operation, learning to learn, respect, responsibility, empathy, self-regulation, and trust (OECD, 2021). Persistence is defined as the effort to consistently engage in challenging tasks without losing focus, despite interruptions, in pursuit of long-term goals (OECD, 2021). The OECD Learning Compass 2030 aims to provide global visions to students, enabling them to achieve moral goals through education that can be learnt at school or beyond,

fostering knowledge, skills, and attitudes that enhance individual, societal, and environmental well-being. The integration of persistence in the curriculum ranks in the bottom 3 (Figure 2). It is believed that although persistence is not a guarantor of success, success cannot be achieved without it (Hill, 2015; Howard & Crayne, 2019).

The nature of learning itself requires persistence because the process is full of obstacles that must be faced, and persistence has been widely recognized as beneficial relative to short-term and ultimately contributes to long-term learning (Israel-Fishelson & Hershkovitz, 2019, 2020; Palacios-Abad, 2021; Salisu et al., 2020; Shechtman et al., 2018). Students with high persistence are highly motivated to achieve high academic performance and are better able to cope with difficulties (Bettinger et al., 2018; DiNapoli, 2023; Edwards & Beattie, 2016; Israel-Fishelson & Hershkovitz, 2020; Palacios-Abad, 2021; Salisu et al., 2020).

The importance of persistence must be accompanied by the development of a scale that serves as a reference for identifying factors that influence persistence. Research on measurement tools for persistence is ongoing. The scale Persistence overlaps significantly with various related categories such as grit, tenacity, self-control, perseverance, goal striving, conscientiousness, goal commitment, dependability, work commitment, ambition, need for achievement, courage, zeal, passion, work ethic, industriousness, stamina, and persistence itself (Howard & Crayne, 2019). The book by Peterson and Seligman is one of the references used to understand aspects of persistence, as cited in DiNapoli (2023), Al Qarni et al. (2023), Smith (2021), and Sowden et al. (2021). These studies also use terms with similar meanings to persistence, such as grit or perseverance. Some scales that contain persistence or have similar connotations include the Persistence Scale/PS-20 (Styk et al., 2023), Persistence, Perseveration and Perfectionism Questionnaire /PPPQ-22 (Styk et al., 2023), Scale for Measuring Persistence in Children (Lufi & Cohen, 1987), Persistence Measure (log-based) (Israel-Fishelson & Hershkovitz, 2019), Grit Scale (Duckworth et al., 2007), Multidimensional Persistence Scale (Howard & Crayne, 2019), Motivational Persistence Scale (Constantin et al., 2012), and the Mathematic Persistence Scale (Marmita et al., 2018; Ogbu & Ugwu, 2023). Each of these tools measures a different aspect of persistence, depending on the study's context and purpose.

Of these measures, the Multidimensional Persistence Scale by Howard and Crayne (2019) was chosen for the current study because it offers a broader, more theoretically integrative conceptualization of persistence. Unlike scales that measure one facet of persistence, Howard and Crayne (2019) consider persistence a multidimensional construct, capturing Persistence Despite Difficulties (PDD), Persistence Despite Fear (PDF), and Inappropriate Persistence (IP). They acknowledge the conceptual overlap between persistence and related constructs such as grit, perseverance, and goal time preference. It combines several related constructs and does not treat persistence as a single, narrowly defined trait. Howard and Crayne (2019) do not consider persistence, grit, and perseverance to be fully distinct constructs with clear conceptual boundaries. Instead, they suggest that persistence-related constructs are highly overlapping, are used interchangeably in some contexts, and may be partially tapping multiple dimensions of the larger construct of persistence. They also explicitly state that it is not yet known whether these constructs are unique or largely overlapping, supporting the view that the literature has not yet established strict theoretical separation between them. This overlap is also evident in the conceptualization of grit by Duckworth et al. (2007), where grit is explicitly defined as "perseverance and passion for long-term goals" which implies that perseverance is already part of the grit construct. Additionally, Howard and Crayne suggest that grit may be a combination of PDD and Goal Time Preference (GTP), further suggesting that grit is best conceptualized as overlapping with the broader persistence domain rather than as distinct from it.

This research also used the framework developed by Howard and Crayne because it is closely related to the OECD Learning Compass 2030. Howard and Crayne (2019) definition of Persistence Despite Difficulties dimension most closely matches the OECD's (2021) definition of persistence as sustained effort on difficult tasks in the face of interruptions to long-term goals, and partially Persistence Despite Fear when interruptions are fear-based. However, Howard and Crayne's model goes beyond the OECD definition to include Inappropriate Persistence, which is the continued effort on unrewarding goals, and separates Goal Time Preference as a related but distinct construct.

Persistence is not a general trait across all educational disciplines, but is rather domain-specific. One can be very persistent in sports, but not in something like math. This specificity is a function of the fact that different domains impose distinct cognitive, emotional, and motivational demands on people. Mathematics, for instance, needs long periods of abstract thought, sophisticated problem-solving skills and the ability to cope with worry about difficult or novel topics – problems somewhat different from those faced in other disciplines. Existing persistence measures are typically insufficient to capture these domain-specific features, notably in mathematics education. Previous studies (e.g., Marmita et al., 2018; Ogbu & Ugwu, 2023) have shown that persistence scales specific to mathematics education usually focus on one primary dimension, that of Persistence Despite Difficulties. This dimension stresses the persistence to overcome mathematics difficulties. This insight is particularly pertinent to the development of the MMPS in the current study. While multiple factors are identified, there is a strong tendency for Persistence Despite Difficulties to emerge as the core dimension, reflecting the essence of students' perseverance in mathematics learning.

A multidimensional scale measuring student persistence must be developed in the context of mathematics education in order to serve as a reference for determining the elements that affect students' academic progress and persistence. Without separating the unique aspects of persistence that affect students' involvement with mathematical assignments, many existing instruments either measure persistence as a broad psychological attribute or confuse it with related notions like grit, perseverance, or motivation. In mathematics education, persistence has a special role. The complexity of the subject requires not only cognitive skills, such as abstract reasoning and problem-solving, but also emotional resilience to overcome anxiety and fear regarding difficult concepts and performance pressure (Ali & Das, 2024; Tulis & Fulmer, 2013). In contrast to general persistence, mathematical persistence is a multi-dimensional construct that requires strategic approaches and emotional regulation to maintain engagement during difficulties. Thus, to evaluate persistence in this field, we require tools that encompass both cognitive and affective dimensions, allowing educators to identify the precise obstacles and resources to enhance learning results.

The Mathematics Multidimensional Persistence Scale (MMPS) was developed to fill this gap by adapting existing frameworks and incorporating dimensions that capture strategic persistence in problem-solving, persistence despite math-specific fears and anxieties, and recognition of inappropriate persistence where efforts are inefficient or counterproductive. This tailored approach enables educators to understand better and support the complex nature of persistence in mathematics contexts.

The purpose of the study is to develop and validate the Mathematics Multidimensional Persistence Scale (MMPS) as a measure of student persistence in the context of mathematics education. The MMPS is adapted from Howard and Crayne (2019) Multidimensional Persistence Scale and is specifically developed to measure persistence in mathematics education. It maintains three core dimensions: Persistence Despite Difficulties (PDD), reflecting students' efforts to persist on difficult math tasks; Persistence Despite Fear (PDF), underscoring the ability to overcome math-related anxiety; and Inappropriate Persistence (IP), identifying counterproductive, rigid persistence strategies. The present research was guided by four main objectives to ensure that the scale is psychometrically robust and valid for the target population: (1) to establish content and face validity through a rigorous expert judgment process involving a multidisciplinary panel of psychologists, language experts and mathematics educators; (2) to identify the factor structure of the adapted items using Exploratory Factor Analysis (EFA); (3) to test construct validity and confirm model fit via Confirmatory Factor Analysis (CFA); and (4) to assess the reliability of the scale through internal consistency analysis.

METHODOLOGY

The development of the Mathematics Multidimensional Persistence Scale (MMPS) followed a systematic scale development framework based on DeVellis (2017) to ensure conceptual clarity and psychometric rigor. The process included the following eight phases:

1. **Clearly Defining What to Measure:** Persistence was conceptualized as a multidimensional construct including Persistence Despite Difficulties, Persistence Despite Fear, and Inappropriate Persistence. This theoretical foundation, adapted from Howard and Crayne (2019), was contextualized for mathematics education and provided a clear conceptual model to guide item development.
2. **Generating an Item Pool:** Items were selected and adapted based on the conceptual model in order to reflect the purpose of the scale, with a focus on persistence in mathematics. The item pool was balanced with positively and negatively worded statements, free of redundancy, and focused on clarity and relevance. This phase involved careful item writing and refinement to ensure full coverage of the construct.
3. **Determining the Measurement Format:** To reliably capture the intensity and nuances of students' persistence-related behaviors and attitudes, a Likert-type response format with multiple response categories was selected, as is common practice in the measurement of attitudinal scales.
4. **Expert Review of Initial Items:** The initial set of items was subjected to a rigorous expert review process to establish content and face validity. A multidisciplinary panel of psychologists, language experts and mathematics education specialists reviewed each item for theoretical relevance, clarity of language and contextual appropriateness. Based on their feedback items were revised and refined. Quantitative assessment of content validity was done using Aiken index and the item pool was found to have high validity scores.
5. **Considering Validation Items:** No additional validation items were added, but expert reviews and subsequent psychometric testing supported the scale's validity, ensuring the instrument's relevance and theoretical soundness.
6. **Administering the Scale to a Development Sample:** The refined scale was administered to a development sample of 438 high school students that is consistent with the recommended participant-to-item ratio of 20:1 for robust factor analysis. This sample size allowed for sufficient statistical power for exploratory and confirmatory analyses.
7. **Item Evaluation:** An Exploratory Factor Analysis (EFA) was conducted to empirically determine the underlying factor structure and to reduce the item pool. This step identified latent constructs related to mathematics persistence and resulted in retention or modification of items. After EFA, a Confirmatory Factor Analysis (CFA) was applied to test the fit of the revised model to the sample data using fit indices such as the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA). Items were evaluated for factor loadings, item-scale correlations and internal consistency resulting in modification and deletion of items that did not perform well.
8. **Optimizing Scale Length:** Items or factors with low reliability or poor psychometric functioning (e.g., the Persistence 2 factor) were excluded to enhance the overall internal consistency and conceptual clarity of the scale, in spite of the difficulties. The final reliability of the MMPS was verified by Cronbach's alpha, which indicated a sufficient internal consistency for research and practice.

Study Population and Sampling

The study was carried out in Manggarai Regency, East Nusa Tenggara, Eastern Indonesia, a predominantly rural area. The population was composed of grade 11 and 12 students from four high schools, all accredited as A or superior. The schools were purposefully chosen because of their high accreditation status and relatively good access to educational resources. The reason for this decision was to minimize the effect of large differences in school quality on student persistence, while controlling for environmental factors that could have a large effect on persistence outcomes. The purpose of the study was to control for, and

better understand, persistence as a student characteristic rather than as a result of significantly different school environments by including schools with similar and advantageous educational conditions.

A convenience sampling method was used due to practical considerations such as accessibility and limited resources. By including schools with high variability in educational quality and environment, we risk introducing confounding factors that may obscure the true measurement of the construct of interest, in this case, persistence in mathematics learning. Thus, choosing schools with relatively homogenous student populations and adequate educational access helps to improve internal validity by reducing extraneous variability due to differences in the environment. This method limits generalizability, but allowed us to recruit a sufficiently large sample (438 students), close to the recommended 20 participants per item for scale validation (Hair et al., 2009). Data collection was conducted from 10 to 25 March 2025.

This research acknowledges the study's sampling limitations and recommend that future research extend the validation of the MMPS to a larger, more diverse sample of schools using more rigorous, probabilistic sampling with respect to school type and accreditation status, and access to education, to confirm the scale's relevance for different educational settings.

Data Collection Scales

The data were gathered using an adapted version of the Multidimensional Persistence Scale (MPS), developed by Howard and Crayne (2019). This adaptation was designed to evaluate students' persistence in mathematics and demonstrates robust psychometric properties and strong validity. This adaptation was designed specifically to evaluate students' persistence in mathematics, providing insight into their ability to sustain effort and overcome challenges in the subject.

The MPS is a self-administered scale comprising three main dimensions: Persistence Despite Difficulties (PDD), Persistence Despite Fear (PDF), and Inappropriate Persistence (IP). The original Multidimensional Persistence Scale (MPS) is a self-administered instrument consisting of three main theoretical dimensions: Persistence Despite Difficulties (PDD), Persistence Despite Fear (PDF), and Inappropriate Persistence (IP). Each dimension is represented by specific items in the questionnaire (See Figure 4). To adapt the scale to the field of mathematics education, additional items were created to capture more fully the aspects of persistence relevant to the learning of mathematics. Exploratory Factor Analysis (EFA) will be used to empirically explore the underlying factor structure of the adapted scale. The present analysis seeks to verify whether the data confirm the theoretical dimensions or if other subdimensions emerge, especially in the context of mathematics. Items will be evaluated on the basis of their factor loadings and psychometric properties to guide decisions about retention or modification, to ensure that the final scale accurately captures the construct of persistence as experienced by mathematics students.

Face Validity and Content Validity

In this study, Face Validity, which assesses the extent to which a measuring instrument appears to measure the intended concept, was first conducted with social research experts. The aim was to assess the scale's readability among students. This evaluation was conducted to ensure that the target users, namely students, easily understood the scale.

Furthermore, the Face Validity and Content Validity evaluations were conducted by a team of three experts: psychologists, language and literature experts, and mathematics education experts. Content Validity, which assesses the extent to which the items in the scale cover all relevant aspects of the concept being measured, is evaluated by considering factors such as grammar, term accuracy, and the relevance of each item to the desired construct. Expert judgement is the basis for ensuring the suitability of the scale for measuring the desired constructs and the relevance of each item.

Construct Validity

Construct validity assesses the adequacy of a scale in measuring the construct it purports to measure. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were used to test the scale's construct validity.

Exploratory Factor Analysis (EFA)

In EFA, scale items that show the highest correlation with each other are grouped into a single factor. Factor analysis is used to determine the number of factors to extract and retain to explain as much of the data as possible. Because this study involved 438 respondents, the minimum factor loading considered to retain each item in the extracted factor was 0.3 (Hair et al., 2009). Thus, only those items with sufficiently strong correlations are retained in the model. The literature presents several established techniques for determining the number of factors to retain during data reduction.

1. An eigenvalue greater than or equal to 1,
2. Scree Plot.
3. Parallel analysis, where the eigenvalues of random data are compared to the eigenvalues of the actual data set.

Parallel analysis can work much better than the previous two methods in identifying the right number of factors.

Sample Sufficiency and Correlation Matrix

To assess sample adequacy, the Kaiser-Meyer-Olkin (KMO) Sample Adequacy Index was used. Next, Bartlett's Test of Sphericity was used to determine whether the scale items showed sufficient correlation to allow integration. This test also ensures that the correlation matrix obtained is significantly different from zero, making it suitable for further analysis.

Table 1. Frequencies of gender by interest

Gender	Interest	Counts	% of Total	Cumulative %
Male	Science	55	12.6	12.6
	Non-sciences	73	16.7	29.3
Female	Science	196	44.7	74
	Non-sciences	114	26	100

Table 2. Frequencies of gender based on likes of mathematics

Gender	Do you like mathematics?	Counts	% of Total	Cumulative %
Male	No	39	7.5	7.5
	Yes	95	21.7	29.2
Female	No	99	22.6	51.8
	Yes	211	48.2	100

Confirmatory Factor Analysis (CFA)

CFA was conducted using Jamovi 2.2 software to evaluate the model. The fit of the model to the data was tested using several indicators, namely:

1. Chi-square test: The Chi-squared model evaluates the overall fit and the difference between the sample and estimated covariance matrices. The p-value should be greater than 0.05 (i.e., the hypothesis of perfect fit cannot be rejected). However, this method is very sensitive to sample size.
2. Root Mean Square Error of Approximation (RMSEA): Root Mean Square Error of Approximation (RMSEA) is an index that indicates how well the statistical model fits the data. RMSEA values closer to 0 indicate good model fit, while values below 0.08 are considered adequate to reflect a suitable relationship between the model and the observed data.
3. Comparative Fit Index (CFI): The Comparative Fit Index (CFI) is a revised form of the Normed Fit Index (NFI). It is less sensitive to sample size. CFI compares the target model's fit to that of the independent model (or the null model). Its value should be greater than 0.96.
4. Normed-Fit Index (NFI)/ Tucker-Lewis Index (TLI): An NFI of 0.95 indicates that the model of interest improves fit by 95%. The Tucker Lewis Index (TLI) is preferred for smaller samples. The TLI value should be greater than 0.90 or greater than 0.95.

Reliability

Internal consistency of the final scale was conducted using Cronbach's alpha coefficient on the target population sample (n = 438). Reliability tests were conducted using Jamovi v2.6.26 software.

Data Analysis

Quantitative variables were summarized using means and standard deviations, and categorical variables were summarized using frequency counts and percentages. Analyses of the demographic characteristics of the research sample, Exploratory Factor Analysis (EFA), and Confirmatory Factor Analysis (CFA) were conducted using Jamovi v2.6.26. For EFA, the 'Minimum Residual' extraction method was employed, with an oblique 'Oblimin' rotation to allow for correlated factors, and the number of factors to retain was determined using parallel analysis. Factor loadings and uniqueness values were examined to interpret the factor structure. For CFA, Full Information Maximum Likelihood (FIML) was used to handle missing data, with factor variances constrained to 1. The analysis reported factor covariances, test statistics, and standardized estimates. Model fit was assessed using the Chi-square (χ^2) test for exact fit, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). Criteria for acceptable model fit included CFI values greater than 0.96 and RMSEA less than 0.08.

RESULTS AND ANALYSIS

Characteristics of the Participants

Table 1 that the gender distribution by specialization is strikingly different between the male and female groupings. 44.7% of the whole population were female students that opted for scientific concentration. Male students are more evenly distributed, with 12.6% opting for science and 16.7% opting for non-science. In the total population, female students are more dominant than male students, especially in the science specialization. The cumulative percentages shown give a thorough view of the contribution of each category to the overall student population analyzed, i.e. 100%.

In **Table 2**, gender distribution according to specialization is found to be remarkably varied between the male and female groups. 44.7% of the total population were female students who selected a scientific concentration. Science and non-science are more evenly split among male students, with 12.6% and 16.7% respectively. Female students are more dominant than male students in the whole population, particularly in the science specialization. The cumulative percentages displayed provide a holistic perspective of the contribution of each group to the overall student population evaluated (100%).

Table 3. Frequencies of gender based on plans after graduating from high school

Gender	Plans after graduating from high school	Counts	% of Total	Cumulative %
Male	Independent Learning (for exploration of interests, such as learning a new skill or taking an online course)	3	0.7	0.7
	Entering the World of Work (Looking for work/internships to gain experience)	14	3.2	3.9
	Continuing Education/College	108	24.6	28.5
	Opening a Business	3	0.7	29.2
Female	Independent Learning (for exploration of interests, such as learning a new skill or taking an online course)	3	0.7	29.9
	Entering the World of Work (Looking for work/internships to gain experience)	21	4.8	34.7
	Continuing Education/College	285	65.1	99.8
	Opening a Business	1	0.2	100

Table 3 displays the gender distribution of the plans of the students after finishing senior high school. They are classified into four major categories, namely self-learning, entering the workforce, continuing education/college and launching a business. The distribution results indicate that majority of the students, both male and female, intend to continue their education. The proportion of female students is substantially larger (65.1%) than that of male students (24.7%). The cumulative numbers further support this fact. A big percentage of the student population is focused on continuing education plans.

Other options such as getting a job (3.2%) and starting a business (0.7%) were more evenly distributed across the male students. However, only 0.2% of the women students intended to start their own firm. The percentage of women in the workforce was higher than that of men (4.8%). The percentage of the self-directed learning choice is 0.7% for males and females. This indicates that, for the majority of pupils, self-directed learning to explore interests is not their top priority.

Content Validity and Face Validity

The scale was examined by professional opinion and the required improvements were made on each item. Feedback highlighted the need to prevent repetition of the term “I” since it causes ambiguity and the need to clarify some items to avoid contradiction with other items. Expert input was used to develop the instrument. The Aiken index for each question ranged from 0.75 to 1.00 and the overall validity index was 0.94. This signifies that all items fall into the very valid category. This interpretation is done by utilizing the criterion of less than 0.4 then it is considered to be low validity, 0.4 -0.8 is said to be moderate validity and more than 0.8 is high validity (Retnawati, 2016).

A team of 3 specialists in the fields of psychology, language and literature, and mathematics education continued the evaluation of face validity and content validity. Face validity is a measure of the clarity and ease of comprehension of the directions for completing the persistence questionnaire. Also, the face validity assures the appropriateness between the grid and the persistence indicators utilized. The statements in the questionnaire should adequately represent students’ persistence, and the question items can be properly used to measure it. The questionnaire has been adapted to the language of the PUEBI guidelines and the sentences are easy to grasp for the responders. The Face validity of Aiken’s index is 0.94 which is considered strong validity.

Exploratory Factor Analysis

Two assumptions need to be tested in this analysis: sphericity and sample concordance (Navarro & Foxcroft, 2025). The initial assumption is sphericity, which checks whether the variables in the data are sufficiently correlated to be summarized by a few factors. Bartlett’s test for sphericity evaluates whether the observed correlation matrix differs significantly from an identity matrix. If Bartlett’s test is significant ($p < 0.05$), then the observed correlation matrix is suitable for Exploratory Factor Analysis (EFA). The second assumption is sample fit, which is tested using the Kaiser-Meyer-Olkin (KMO) measure. KMO measures the proportion of variance between variables that may be shared variance. A small KMO value (< 0.5) indicates that the EFA is not suitable, whereas higher KMO values indicate a better fit. Values between 0.5–0.7 are considered adequate, 0.7–0.9 good, and 0.9–1.0 very good (Navarro & Foxcroft, 2025). The Bartlett’s Test of Sphericity analysis yielded a value of $\chi^2 = 1888$ with degrees of freedom (df) = 210 and $p < 0,001$. This indicates a statistically significant correlation between variables, making the data eligible for further factor analysis. In addition, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy Overall yielded a value of 0.837, indicating an excellent level of sampling adequacy for conducting a factor analysis. These statistical prerequisites confirm that the data are suitable for factor analysis, aligning with the theoretical expectation of multidimensional persistence constructs. After that, Exploratory Factor Analysis (EFA) was performed using Minimum Residual extraction method with Oblimin rotation to find the factor structure and latent correlations among variables. Then, the number of factors in exploratory factor analysis (EFA) is determined through the parallel analysis method. The number of factors is determined by the Eigen value of the actual data and the Eigen value of the random data and only the factor with an Eigen value greater than the random value is retained. It is claimed to be a good one according to Fabrigar et al. (1999). **Table 4** shows that Persistence Despite Difficulties (PDD) and Persistence Despite Fear (PDF) each split into two subdimensions, while Inappropriate Persistence (IP) remained a single factor.

Table 4. Factor loadings

Indicators	Factor Loadings	Uniqueness	KMO MSA
Persistence Despite Difficulties 1			
PDD6 If I have a difficult math problem, I break it down into simpler steps.	0.620	0.609	0.868
PDD10 I try another way to solve a math problem when the previous method doesn't work	0.595	0.594	0.844
PDD8 I usually draw pictures, diagrams, or doodles to help me understand difficult math concepts.	0.524	0.736	0.881
PDD17 I try to redo the problem when I don't get a good grade in math	0.395	0.61	0.914
PDD2 When I fail to solve a difficult math problem, I still have the enthusiasm to solve it.	0.324	0.673	0.873
Persistence Despite Difficulties 2			
PDD16 When I realize that I made a wrong move in solving a problem, I rework it with enthusiasm.	0.545	0.518	0.884
PDD11 I ask my teacher or friends for help with difficult math problems	0.388	0.834	0.721
PDD18 I don't get discouraged when I answer a math problem wrongly	0.357	0.817	0.882
Persistence Despite Fear 1			
PDF19R If there is a difficult math exercise, I usually just give up	0.827	0.316	0.764
PDF4R I give up when given a math assignment that cannot be solved immediately	0.549	0.669	0.776
Persistence Despite Fear 2			
PDF14 I keep trying to complete the homework given by the teacher even though I don't understand the math concept	0.621	0.607	0.737
PDF13 If I am asked to solve a problem on the board, I keep going even though I don't know the answer.	0.458	0.742	0.819
PDF15 I try to solve new math problems using methods that I have learned before, even though I may not be able to solve them well.	0.378	0.743	0.861
PDF5 I keep solving math problems even though my friends have given up.	0.300	0.625	0.903
Inappropriate Persistence			
IP21 I repeat the same steps to solve math problems, even though there is a simpler way.	0.763	0.407	0.692
IP20 I keep using the same method to solve math problems, even though I know it is not effective in finding solutions.	0.619	0.546	0.685
IP22 I still use a certain way to solve math problems, even though I know it won't produce the right answer.	0.605	0.581	0.709

Table 5. Test for exact fit

χ^2	df	p
185	94	< .001

Table 6. Fit indices for confirmatory factor analysis model (n = 438)

Model Fit Indices	CFI	TLI	RMSEA	χ^2/df
Confirmatory factor analysis	0.924	0.903	0.0469	1.96
Thresholds for acceptable fit	> 0.90	> 0.90	< 0.08	< 3
Thresholds for good fit	> 0.95	> 0.95	< 0.05	< 2

This factor solution supports the multidimensional nature of persistence hypothesized in the conceptual framework, indicating distinct but related persistence dimensions in mathematics learning.

This multidimensional factor structure corroborates the findings of Howard and Crayne (2019) and Constantin et al. (2012), who emphasize the complexity of persistence involving cognitive, emotional, and behavioral components. The split of Persistence Despite Fear into avoidance and effortful persistence subdimensions aligns with research highlighting the role of anxiety in persistence behaviors (Ali & Das, 2024; Israel-Fishelson & Hershkovitz, 2019).

Confirmatory Factor Analysis

The chi-square (χ^2) statistic used to evaluate model fit is highly sensitive to sample size. In large samples, even trivial discrepancies between the model and data can produce a statistically significant χ^2 value ($p < .05$), potentially leading to the incorrect rejection of an otherwise adequate model. The analysis results show a statistical model fit test that includes several important measures for model evaluation, with a value of χ^2 of 185 with degrees of freedom (df) 94, and p-value < .001 (See **Table 5**). Because the p-value is so small, it indicates that the model does not have a perfect fit and rejects the ideal fit hypothesis. However, the Chi-squared test is very sensitive to sample size, so in large-sample studies, this result is quite common (Navarro & Foxcroft, 2025).

This research uses alternative methods to assess model fit, with a threshold for acceptable fit, as in Negarandeh et al. (2024) and Kline (2016). A Comparative Fit Index (CFI) of 0.924 and a Tucker-Lewis Index (TLI) of 0.903 were obtained, indicating a reasonably good fit between the model and the observed data (See **Table 6**). In addition, the Root Mean Square Error of Approximation (RMSEA) value of 0.0469, with a 90% confidence interval of 0.0368-0.0568, supports the conclusion that the model has a relatively low error rate in representing the data. Overall, these results indicate that the model used meets the fit standard required for validating research instruments. These fit indices indicate that the proposed multidimensional persistence model appropriately represents the data, thus supporting the theoretical structure of the MMPS.

Table 7. Scale reliability statistics

Factors	Cronbach's α (by factor)	Cronbach's α
Persistence Despite Difficulties 1	0.689	0.723
Persistence Despite Difficulties 2	0.450	
Persistence Despite Fear 1	0.655	
Persistence Despite Fear 2	0.573	
Inappropriate Persistence	0.712	

Reliability

The results of the analysis of the reliability of the scale show that Cronbach's value can be seen in **Table 7**. The Inappropriate Persistence factor showed good reliability ($\alpha = 0.712$), while Persistence Despite Difficulties 1 was marginally acceptable ($\alpha = 0.689$). Persistence Despite Difficulties 2 had low reliability ($\alpha = 0.450$) and was excluded from further analysis. Persistence Despite Fear 1 and 2 showed moderate reliability ($\alpha = 0.655$ and 0.573 , respectively), and planned item revisions were planned to improve internal consistency.

This variability in reliability reflects the complexity of measuring multidimensional psychological constructs like persistence and indicates areas for further refinement, consistent with common challenges in psychometric scale development.

Reliability by factor

The reliability analysis per factor showed variations in internal consistency:

- Persistence Despite Difficulties 1 ($\alpha = 0.689$): Values close to the acceptance threshold ($\alpha \geq 0.70$) indicate marginal/moderate reliability. Although the Cronbach's Alpha value for the Persistence Despite Difficulties 1 factor ($\alpha = 0.689$) was slightly below the ideal threshold ($\alpha \geq 0.70$), this factor was retained in the analyses with the consideration that in social and psychological research, α values between 0.60-0.70 are often considered *acceptable* for new scales or complex constructs (DeVellis, 2017).
- Persistence Despite Difficulties 2 ($\alpha = 0.450$): The results of the reliability analysis indicate that the Persistence Despite Difficulties 2 factor is unacceptable (DeVellis, 2017). This value is well below the minimum reliability standard ($\alpha \geq 0.60$), indicating that the items in the factor do not consistently measure the same construct. Therefore, this factor was excluded from further analysis.
- Persistence Despite Fear 1 ($\alpha = 0.655$): The score is moderate but below 0.70. This factor may require re-examination of its items to improve consistency.
- Persistence Despite Fear 2 ($\alpha = 0.573$): Although the α value for the Persistence Despite Fear 2 factor ($\alpha = 0.573$) was slightly below the 0.60 threshold, this factor was retained given its proximity to the minimum value and the urgency of the construct in the study. Nonetheless, this value is close enough to the reliability criteria, so this factor is retained with a note that revisions to the constituent items are needed. However, the interpretation of the results related to this factor is done with caution.

Revised items to improve the reliability of the Persistence Despite Fear 2 factor ($\alpha = 0.573$) by clarifying construct consistency, reducing ambiguity, and strengthening the persistence despite fear/anxiety dimension:

- PDF14 reflects a student's persistence in learning: "I still try to complete the homework given by the teacher even though I don't understand the mathematical concept." This statement was revised to "I kept trying to complete the math's homework even though I was unsure of my understanding, rather than giving up immediately" to more explicitly highlight the emotional barrier (uncertainty) and contrast it with the choice to persevere. The revision strengthens the focus on persistence by framing the struggle as an active decision to continue despite doubt, rather than passive confusion.
- PDF13 demonstrates a student's willingness to engage with challenges despite discomfort: "If I am asked to solve a problem on the board, I go ahead even if I don't know the answer." This statement was refined to "I am willing to try to solve problems in front of the class even though I feel anxious that I will make mistakes," shifting the focus from general uncertainty ("don't know") to the specific emotional barrier of error anxiety. The revision aligns with the fear construct by emphasizing the learner's vulnerability to mistakes, a more precise deterrent than mere lack of knowledge, while still highlighting their persistence in attempting the task.
- PDF15 illustrates a student's adaptive problem-solving approach: "I try to solve new math problems in ways that I have learnt before, even though I may not be able to solve them well." This was revised to "I try the different ways I know to solve new math problems, even if I'm afraid the results won't be perfect," to explicitly incorporate the emotional dimension of fear (specifically, fear of imperfect outcomes) while eliminating the redundant phrasing about incomplete success. The refined version better captures the psychological tension between persistence and the anxiety of falling short, aligning with the broader theme of emotional barriers in learning.
- PDF5 demonstrates continuous effort in peer learning environments: "I continue to solve math problems even though my friends have given up." This statement was enhanced to "I keep trying to solve math problems even when my friends give up, even when I doubt my own ability," introducing the crucial element of self-doubt as an internal emotional barrier. While the original version focused solely on social comparison (persisting where peers quit), the revision adds psychological depth by acknowledging the student's internal struggle with confidence. This dual

emphasis on both external peer influence and internal self-doubt provides a more comprehensive view of the challenges students face when demonstrating persistence in mathematics.

- e. Inappropriate Persistence ($\alpha = 0.712$): The Inappropriate Persistence factor demonstrated good reliability (Cronbach's $\alpha = 0.712$). This value has met and slightly exceeded the recommended minimum threshold ($\alpha \geq 0.70$), so it can be categorized as having adequate internal consistency (acceptable) for measurement in the research context.

Overall reliability (Overall scale)

Reliability analysis showed significant improvement after revision. The initial Cronbach's alpha value was 0.723, and increased to 0.749. This final score not only exceeds the recommended minimum threshold ($\alpha \geq 0.70$) but is also good for a newly developed instrument (DeVellis, 2017). Although it has not reached excellent reliability ($\alpha \geq 0.80$), these results indicate that the scale has consistently measured the target construct. This finding provides a sufficient basis for further use, with the caveat that additional refinements may improve measurement precision in future research.

The reliability analysis showed variations in internal consistency across the instrument's factors. Overall, the scale has achieved adequate reliability with a Cronbach's alpha value of 0.749 after refinement, which is considered acceptable and even good for a newly developed instrument. This value provides a strong basis for using the instrument in this study, although there is still room for improvement.

Some factors showed satisfactory performance. The Inappropriate Persistence factor recorded an alpha value of 0.712, which met the minimum standard. Similarly, Persistence Despite Difficulties 1 ($\alpha = 0.689$), which, although slightly below the 0.70 threshold, is still tenable given the complexity of the construct measured in social research. However, the factor Persistence Despite Difficulties 2 ($\alpha = 0.450$) was excluded from the analysis because it did not meet the minimum reliability criteria. For factors with marginal reliabilities, such as Persistence Despite Fear 1 ($\alpha = 0.655$) and Persistence Despite Fear 2 ($\alpha = 0.573$), items were revised to improve internal consistency. These revisions focused on aligning the items with the core constructs and on emphasizing the emotional aspects (fear and anxiety) as barriers. These editorial improvements are expected to improve measurement reliability in future research. This finding underscores that although the instrument as a whole has met basic reliability requirements, further refinement is still needed.

DISCUSSION

Validation and Psychometric Properties

The results of content validity and face validity show that the instrument has high quality in measuring students' persistence. Expert input in psychology, language, and math education has significantly improved the clarity and relevance of the questionnaire items. The Aiken's index, which ranges from 0.75 to 1.00 and has a total average of 0.94, indicates that the items in this scale are highly valid. This finding supports the conclusion that the instrument accurately reflects students' persistence indicators and is relevant to the research objectives. In the exploratory factor analysis (EFA), the KMO value of 0.837 and the significant Bartlett's test results indicated that the data qualified for further factor analysis. The resulting factor structure identified important elements of persistence, such as Persistence Despite Difficulties and Persistence Despite Fear, which showed patterns consistent with the theoretical concept of persistence. In contrast, the Inappropriate Persistence factor provided important insights into less effective persistence behaviors, which could be the focus of further development.

These identified factors align with and extend existing persistence theories, particularly the multidimensional framework proposed by Howard and Crayne (2019), which emphasizes different dimensions of persistence, including persistence despite challenges and maladaptive persistence.

Confirmatory factor analysis (CFA) corroborated the factor structure, with CFI and TLI values of 0.924 and 0.903, respectively, in the moderately good fit category, and an RMSEA of 0.0469, indicating a low level of data misrepresentation. Although the Chi-squared test produced significant values due to sensitivity to sample size, the other fit indices indicated that the model used was adequate in instrument validation.

These fit indices demonstrate that the revised model reliably captures the underlying persistence constructs within the mathematics education context, affirming the scale's construct validity in line with psychometric standards (Kline, 2016).

From the reliability analysis, the Cronbach's α value of 0.749 indicates a fairly good internal consistency. Although still in the moderate category, this value is sufficient to support the instrument's use in research on student persistence, with opportunities for future refinement. Analysis of the items in each factor revealed the need to revise the nomenclature to reflect better the construct being measured. This change is based on the characteristics of the items comprising each factor and their alignment with the relevant literature.

Theoretical Alignment and Factor Interpretation

After removing the problematic Persistence Despite Difficulties 2 factor due to its unacceptably low reliability ($\alpha = 0.450$), the revised framework now presents three clearly defined dimensions of persistence in mathematics learning. The remaining factors demonstrate improved conceptual clarity and psychometric properties. The previous factor, named Persistence Despite Difficulties 1, was changed to "Strategic Persistence in Mathematics". This name was chosen because the items in this factor measure systematic approaches to dealing with mathematical difficulties, such as breaking problems down into simpler steps (PDD6), trying alternative methods (PDD10), and using visual aids (PDD8). This factor not only captures aspects of general

persistence but is more specific to structured and adaptive problem-solving strategies. Persistence Despite Fear factor 1 was revised to “Math Avoidance Due to Difficulty”. This name better reflects the factor’s content, as all items are reverse-coded and explicitly measure the tendency to give up or avoid difficult math problems (PDF19R, PDF4R).

Meanwhile, the Persistence Despite Fear 2 factor was changed to “Effortful Persistence Despite Math Anxiety”. This name reflects the essence of its constituent items, which show persistent effort despite doubt or anxiety, such as continuing to do homework despite not fully understanding (PDF14) or, in the future, doing problems on the board despite being unsure of the answer (PDF13). This change in the factor name not only increases conceptual precision but also facilitates differentiation among constructs in subsequent analyses. This revision aligns with recent research that emphasizes a multidimensional approach to understanding academic persistence. This thematic separation and renaming align with related constructs such as grit, perseverance, and anxiety-related persistence identified in previous studies (Ali & Das, 2024; DiNapoli, 2023), highlighting the interplay between cognitive and affective dimensions in persistence.

Practical Implications for Mathematics Education

The revision of the Multidimensional Mathematics Persistence Scale (MMPS) framework, which resulted in four main factors, has important implications for the application of differentiated learning in mathematics education in Indonesia. Differentiated learning emphasizes tailoring instruction to students’ individual needs, and these four MMPS factors provide concrete guidance for teachers in designing more effective strategies.

The Strategic Persistence in Mathematics factor, which includes systematic approaches such as breaking down problems into simple steps or trying alternative methods, can be integrated into differentiated learning through ability-based scaffolding. Teachers can divide the class into small groups based on understanding level, then provide different think-aloud models for each group. This aligns with the principle of differentiated learning in Indonesia, where teachers are required to accommodate students’ diverse learning styles and abilities. Research by Oren Ozdemir et al. (2024) on mathematical metacognitive awareness underscores the importance of the differentiation approach by showing that mathematical monitoring directly affects academic resilience, which is closely related to persistence. This finding aligns with the principle of differentiated learning, which emphasizes adjusting learning strategies based on students’ metacognitive profiles. Teachers can model metacognitive processes for lower ability students, while more advanced students are challenged to design independent solutions. In addition, research by Syahbana and Nopriyanti (2024) on self-efficacy revealed that students’ beliefs about their abilities influence persistence in learning. The self-efficacy instrument, which is closely related to persistence, can be used by teachers to identify students who need motivational support, such as mastery-oriented feedback or strength-based reflection.

The Math Avoidance Due to Difficulty factor is an important indicator for teachers in identifying students who tend to avoid math when faced with difficulties. In the context of differentiated learning, MMPS assessment results can be used to design personalized interventions, such as differentiated tasks with gradual difficulty levels. For example, students who show high avoidance tendencies can be given problems with more relevant daily-life contexts, while students with low avoidance tendencies can be given more complex challenges. This approach can also be reinforced with growth mindset intervention strategies, such as providing mastery-oriented feedback that emphasizes individual development rather than a final grade. In Indonesia, where math anxiety is high, this approach can help reduce math avoidance and increase motivation to learn. Research by Ali & Das (2024) also revealed that math anxiety has an indirect effect on problem-solving achievement through math interest. Therefore, reducing students’ anxiety by providing appropriate tasks and emotional support can increase their interest and confidence.

The Effortful Persistence Despite Math Anxiety factor underlines the importance of creating a psychologically safe classroom. In differentiated learning, teachers can apply techniques such as productive struggle activities or mistake-normalizing group discussions. For example, students with high anxiety levels could be given more time and peer-supported problem-solving, while more confident students could be given open-ended problems. In Indonesia, where academic pressure often triggers anxiety, this approach could help students develop resilience and perseverance in learning math. Findings Ali & Das (2024) showed that self-efficacy, which is closely related to persistence, mediates the effects of mathematical anxiety on problem-solving achievement, so efforts to reduce anxiety and increase interest can indirectly improve students’ persistence.

Meanwhile, the Inappropriate Persistence factor reminds teachers to help students develop strategy flexibility. In differentiated learning, teachers can design activities such as strategy-flexibility training, where students are invited to compare various problem-solving methods. For example, through task differentiation, students can be asked to solve one problem in two different ways and then reflect on which one is more effective. This approach is particularly relevant in Indonesia, where maths learning often still focuses on a single procedure. By practicing strategy flexibility, students can avoid inappropriate persistence and become more adaptive in problem solving. This approach aligns with the generality dimension of the self-efficacy scale by Syahbana and Nopriyanti (2024), which emphasizes students’ confidence in applying knowledge across various contexts.

The revised MMPS framework is not only psychometrically sound, but also provides practical classroom advantages as a formative assessment tool within the mathematics curriculum. MMPS is not a static measure, but rather supports teachers during instructional units by providing diagnostic clarity about student persistence profiles. This is not to be a hard and fast taxonomy but rather a way of charting persistence traits and helping educators target support for challenges in nonroutine problem solving. MMPS helps teachers identify which types of support (e.g., scaffolding, strategy-flexibility training, motivational feedback) work best to foster adaptive persistence and enhance mathematical learning.

The MMPS allows educators to track student progress, recognize at-risk behaviors such as avoidance or anxiety, and customize interventions to meet various learning needs. Students who avoid mathematics due to its perceived difficulty can be given contextualized tasks and growth-mindset reinforcement, and students who exhibit strategic persistence can be offered open-ended investigations. By recognizing effortful persistence through anxiety, teachers can foster psychologically safe spaces and

opportunities for productive struggle. The recognition of inappropriate persistence points to the need for strategy-flexibility training. MMPS serves as a formative assessment that informs instruction, supports differentiation, and aligns with the Merdeka Curriculum's student-centered approach. This enhances the credibility of the assessment and provides practical, evidence-based guidance for cultivating adaptive persistence.

The improved MMPS framework improves the assessment and instructional guidance of differentiated learning and formative assessment in the Indonesian mathematics education. The integration of MMPS helps teachers to address the diversity of students in cognitive strategies, anxiety management and mindset development. The approach is in line with the Merdeka Curriculum student-centred learning and is a strategy to improve the quality of mathematics education. Regular use of MMPS as a formative tool allows for tracking persistence, timely support and reinforcement of adaptive strategies to build resilience.

Contributions and Future Directions

This study made an important contribution to the development of a student persistence scale in mathematics education. The instrument is not only valid in content and appearance, but also has adequate factor structure and reliability. The findings have the potential to provide a foundation for developing more effective educational strategies to increase students' persistence in overcoming the challenges of learning mathematics, especially in remote areas or with limited access to education. Also, the results of this study are expected to support educators in understanding and measuring the factors that influence students' persistence in learning mathematics, and to help educators enhance students' persistence in mathematics through personalized, data-driven strategies that foster adaptive learning and improve instruction. Future research should focus on validating the MMPS across diverse populations and on the longitudinal impacts of persistence-informed interventions on academic outcomes. Refinement of subfactors with lower reliability is also necessary to improve measurement precision.

CONCLUSION

The Mathematics Multidimensional Persistence Scale (MMPS) was successfully developed and validated as a reliable instrument to evaluate students' persistence in mathematics education. By adapting the Multidimensional Persistence Scale by Howard and Crayne (2019), the MMPS underwent rigorous translation, expert review, and testing, resulting in a culturally relevant scale comprising 22 items. The scale was tested on 438 high school students from Manggarai, East Nusa Tenggara, Eastern Indonesia, and demonstrated strong psychometric properties. Data analysis using Jamovi V.2.6.26 revealed that the items split into four reliable factors: Strategic Persistence in Mathematics, Math Avoidance Due to Difficulty, Effortful Persistence Despite Math Anxiety, and Inappropriate Persistence. Confirmatory Factor Analysis (CFA) indicated that the revised model provided a good fit to the sample data ($CFI = 0.924$, $TLI = 0.903$, $RMSEA = 0.0469$). These findings highlight the potential of MMPS to advance persistence theory and develop effective evaluation tools in mathematics education.

The present study focused on students in grades 11 and 12 of senior high schools located in Manggarai, a rural area in East Nusa Tenggara, Indonesia. While this provides valuable insights into persistence traits within this specific demographic, it may limit the generalizability of findings to other age groups or educational contexts. Future studies could extend the evaluation of the Mathematics Multidimensional Persistence Scale (MMPS) to students from various grade levels, educational systems, and geographic settings, including urban areas, to enhance its applicability and robustness across diverse populations.

The Mathematics Multidimensional Persistence Scale (MMPS) serves as a powerful tool for educators to enhance students' persistence in mathematics through targeted, data-driven strategies. By identifying individual persistence profiles, teachers can provide personalized support, whether by strengthening problem-solving skills, reducing anxiety, or fostering adaptive learning habits. The integration of MMPS into classroom practices, from goal-setting to progress monitoring, enables a shift from generic encouragement to structured, evidence-based interventions. Furthermore, its application in professional development equips educators with the skills to cultivate a culture of persistent learning. As education increasingly prioritizes adaptability and persistence, the MMPS offers a practical framework to nurture these competencies, ultimately contributing to more effective and inclusive mathematics instruction. Future research should explore the long-term impact of MMPS-informed teaching on student achievement and engagement in the Mathematics Education environment.

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