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# Validity and Reliability of the Mathematics Academic Self-Concept (MASC) Scale Through Confirmatory Factor Analysis (CFA)

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**Abstract**

This study evaluated the psychometric properties of a mathematics-specific adaptation of Liu and Wang's Academic Self-Concept scale among 252 senior high school students. The 20-item Mathematics Academic Self-Concept (MASC) scale was specified as two correlated factors: Mathematics Academic Confidence and Mathematics Academic Effort. Item–rest correlations ranged from 0.299 to 0.616. Confirmatory factor analysis with ordinal indicators and DWLS estimation yielded inadequate global fit (RMSEA = 0.154, CFI = 0.852, TLI = 0.833, SRMR = 0.121, NFI = 0.831, and IFI = 0.852), although GFI was 0.935. Average variance extracted was 0.310 for Confidence and 0.305 for Effort, while composite reliability was approximately 0.817 and 0.810, respectively. The latent-factor correlation was 0.817, exceeding the square root of AVE for each factor and failing the Fornell–Larcker criterion. Cronbach's alpha values were 0.778 for Confidence, 0.756 for Effort, and 0.853 for the full scale. Thus, the scale demonstrated internal consistency, but the present analysis did not establish satisfactory factorial, convergent, or discriminant validity. Further theory-informed investigation and independent validation are required.

**Keywords:** Mathematics Academic Self-Concept, Construct Validity, Reliability, Confirmatory Factor Analysis

## 1. Introduction

Students' mathematics achievement is associated with cognitive as well as affective factors, including academic self-concept (Ding, Klapp, & Hansen, 2024; Granello et al., 2025). Academic self-concept refers to students' perceptions of their academic competence and their capacity to

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learn successfully (Kaedabi-Donkor et al., 2025). Research has linked it to motivation, persistence, and achievement (Sewasew & Schroeders, 2019; Tanadi, Hartini, & Putra, 2020; Abaidoo et al., 2021).

Liu and Wang (2005) developed an academic self-concept scale for secondary school students in Singapore. It distinguishes academic confidence, or perceived academic competence, from academic effort, which concerns students' engagement and willingness to work on academic tasks (Lesmana, 2019). These dimensions provide a starting point for examining self-concept in a particular subject.

The scale has subsequently been examined in other educational settings. Matovu (2014) tested its two-factor structure using structural equation modeling, while Granero-Gallegos et al. (2021) studied a Spanish adaptation through exploratory and confirmatory factor analyses and examined measurement invariance. Such findings support further investigation of the scale, rather than assuming that its structure will remain unchanged across contexts.

Because the original items refer to academic work generally, they may not fully capture how students perceive their abilities and efforts in mathematics. This distinction matters: mathematics learning is shaped by students' confidence, anxiety, and experiences with challenging tasks (Delima & Cahyawati, 2021; van Hoogmoed et al., 2024; Granello et al., 2025). Mathematics self-concept has also been associated with engagement and achievement (Kaskens et al., 2020; Agustina, Kismiantini, & Radite, 2024). A mathematics-specific adaptation therefore warrants empirical testing.
Research on students' mastery profiles has also been used to reconsider the selected topics in mathematics education courses (Purba et al., 2025), illustrating the value of evidence about students' mathematical knowledge when making educational decisions.

Adapting item wording is not sufficient to establish that the original two-factor structure applies to mathematics. Confirmatory factor analysis (CFA) can test whether the observed responses are consistent with the proposed confidence and effort factors (Putri et al., 2023; Umar & Nisa, 2020). Reliability analysis offers separate evidence about the consistency of scores. Both forms of evidence are needed when assessing an adapted instrument.

This study therefore aimed to adapt the Liu and Wang scale to mathematics, test the proposed two-factor structure using CFA, and assess score reliability among senior high school students.

## 2. Methods

The study used a mathematics-specific Indonesian adaptation of Liu and Wang's (2005) Academic Self-Concept scale, retaining the confidence and effort dimensions examined in earlier work

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(Matovu, 2014; Granero-Gallegos et al., 2021). The 20-item Mathematics Academic Self-Concept (MASC) scale assigned odd-numbered items to Mathematics Academic Confidence and even-numbered items to Mathematics Academic Effort. Responses used a seven-point Likert scale from Strongly Disagree to Strongly Agree. Table 1 presents the adapted items.

A total of 252 senior high school students provided responses to the 20 MASC items, rated on a seven-point Likert scale. Negatively worded items were reverse-scored before analysis, as confirmed by the researchers. The dataset was analyzed in JASP (Version 0.95.4). The output identifies corrected item–rest correlations in the reliability analysis and a two-factor CFA estimated with diagonally weighted least squares (DWLS), treating indicators as ordinal. The specified factors were Mathematics Academic Confidence (10 odd-numbered items) and Mathematics Academic Effort (10 even-numbered items). Global fit was assessed using chi-square significance, RMSEA, CFI, TLI, SRMR, GFI, NFI, and IFI. Standardized loadings, average variance extracted (AVE), composite reliability (CR), and the estimated factor correlation were used to examine psychometric evidence. Discriminant validity was evaluated by comparing the square root of each factor's AVE with the absolute latent-factor correlation (Fornell & Larcker, 1981).

Table 1. Modified Mathematics Academic Self-Concept (MASC) Scale

| No. | Mathematics Academic Self-Concept Scale Items | Original Subscale |
|---|---|---|
| 1 | I can follow mathematics lessons easily. | academic confidence |
| 2 | I often daydream during mathematics lessons. | academic effort |
| 3 | I am able to help my classmates with mathematics assignments. | academic confidence |
| 4 | I often complete mathematics assignments without thinking carefully. | academic effort |
| 5 | If I study hard, I believe I can achieve better mathematics scores. | academic confidence |
| 6 | I pay attention to the teacher during mathematics lessons. | academic effort |
| 7 | Most of my classmates are better at mathematics than I am. | academic confidence |
| 8 | I study hard when preparing for mathematics tests. | academic effort |
| 9 | My teacher thinks that my mathematics ability is not very good. | academic confidence |
| 10 | I am usually interested in mathematics lessons. | academic effort |
| 11 | I often forget the mathematics material that I have learned. | academic confidence |
| 12 | I will do my best to achieve good grades in mathematics this semester. | academic effort |
| 13 | I feel anxious when the mathematics teacher asks me questions. | academic confidence |

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| | | |
|---|---|---|
| 14 | I often feel like giving up when learning mathematics. | academic effort |
| 15 | I am fairly good at most mathematics topics. | academic confidence |
| 16 | I often wait for mathematics lessons to end quickly. | academic effort |
| 17 | I usually obtain poor scores on mathematics assignments and tests. | academic confidence |
| 18 | I do not give up easily when facing difficult mathematics problems. | academic effort |
| 19 | I am able to achieve better results than many of my classmates in mathematics. | academic confidence |
| 20 | I am unwilling to put in more effort when completing mathematics assignments. | academic effort |

## 3. Result and Discussion

### 3.1 Item–Rest Correlation Analysis

The item statistics in Table 2 were traced to the 'Frequentist Individual Item Reliability Statistics' output in JASP (Version 0.95.4), with the 'item–rest correlation' option selected. Each estimate is the correlation between an item and the score for the remaining items, not a Rasch infit/outfit measure or an item response theory fit statistic. Item–rest correlations were examined descriptively as part of internal-consistency analysis; they do not constitute a separate test of CFA model fit.

Table 2. Corrected Item–Rest Correlations

| Item | Estimate |
|---|---|
| AC1 | 0.476 |
| AE2 | 0.526 |
| AC3 | 0.418 |
| AE4 | 0.345 |
| AC5 | 0.325 |
| AE6 | 0.346 |
| AC7 | 0.397 |
| AE8 | 0.299 |
| AC9 | 0.498 |
| AE10 | 0.550 |
| AC11 | 0.410 |
| AE12 | 0.326 |
| AC13 | 0.523 |
| AE14 | 0.616 |
| AC15 | 0.423 |
| AE16 | 0.494 |

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| | |
|---|---|
| AC17 | 0.534 |
| AE18 | 0.415 |
| AC19 | 0.469 |
| AE20 | 0.354 |

Corrected item–rest correlations ranged from 0.299 (AE8) to 0.616 (AE14). All estimates were positive; AE8 was close to the commonly used descriptive reference of 0.30. These associations suggest that the items generally align with the remaining scale items, but they cannot establish dimensionality, inferential item fit, or adequate construct validity. Item retention should therefore be considered in conjunction with item content and CFA evidence.

### 3.2 Confirmatory Factor Analysis (CFA)

Before factor analysis, sampling adequacy was examined using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity. These procedures assess whether the observed correlations are suitable for factor analysis, but they are not tests of the proposed CFA model itself (Amerioun et al., 2018).

Table 3. KMO (Kaiser Meyer-Olkin) test dan Bartlett's Test of Sphericity

| KMO (Kaiser Meyer-Olkin) test dan Bartlett's Test of Sphericity | | |
|---|---|---|
| Kaiser-Meyer-Olkin (KMO) | | 0.818 |
| Bartlett's test of sphericity | $X^2$ | 1959 |
| | df | 190 |
| | p | < .001 |

The KMO value was 0.818, and Bartlett's test was significant ($\chi^2 = 1959$, df = 190, $p < 0.001$). The data therefore showed sufficient inter-item correlation for factor analysis. These results should not, however, be interpreted as evidence that the hypothesized two-factor model fits the data.

CFA tests the proposed relationship between observed items and latent factors against the covariance patterns in the data. A significant chi-square test ($p < 0.05$) rejects exact model fit; it does not indicate that the model is acceptable. Because the chi-square test is influenced by sample size and model complexity, the result is considered alongside approximate fit indices (Stone, 2021).

RMSEA reflects approximate misfit, and CFI indicates improvement relative to a baseline model. Other measures, including SRMR and TLI, can help clarify the pattern of fit. Rather than treating any one cutoff as decisive, the indices should be interpreted jointly and in relation to the model being evaluated (Goretzko et al., 2024; Groskurth et al., 2024). Table 4 summarizes the indices available for this study.

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Table 4. Results of the Goodness of Fit (GoF) Analysis of the Mathematics Academic Self-Concept (MASC) Scale

| Matrix | Criteria | Value | Interpretation |
|---|---|---|---|
| Chi-square exact-fit test | p > .05 | p < .001 | Misfit |
| RMSEA | < .08 | 0.154 | Misfit |
| GFI | > .90 | 0.935 | Favorable |
| CFI | > .90 | 0.852 | Misfit |
| TLI | > .90 | 0.833 | Misfit |
| SRMR | < .08 | 0.121 | Misfit |
| NFI | > .90 | 0.831 | Misfit |
| IFI | > .90 | 0.852 | Misfit |

The JASP results show RMSEA = 0.154 (90% CI [0.145, 0.162]), CFI = 0.852, TLI = 0.833, SRMR = 0.121, NFI = 0.831, and IFI = 0.852. Although GFI = 0.935 exceeded a conventional reference of 0.90, the overall pattern indicates inadequate fit of the unmodified two-factor CFA model.

Table 5. Factor Loading Mathematics Academic Self-Concept (MASC)

| Factor | Indicator | Std. estimate |
|---|---|---|
| Mathematics Academic Confidence | AC1 | 0.579 |
| | AC3 | 0.517 |
| | AC5 | 0.483 |
| | AC7 | 0.515 |
| | AC9 | 0.612 |
| | AC11 | 0.489 |
| | AC13 | 0.600 |
| | AC15 | 0.512 |
| | AC17 | 0.644 |
| | AC19 | 0.596 |
| Mathematics Academic Effort | AE2 | 0.599 |
| | AE4 | 0.400 |
| | AE6 | 0.492 |
| | AE8 | 0.428 |
| | AE10 | 0.647 |
| | AE12 | 0.543 |
| | AE14 | 0.726 |
| | AE16 | 0.563 |
| | AE18 | 0.538 |
| | AE20 | 0.511 |

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Standardized loadings for Mathematics Academic Confidence ranged from 0.483 to 0.644, and loadings for Mathematics Academic Effort ranged from 0.400 to 0.726 (Table 5). The complete JASP output reports AVE values of 0.310 for Confidence and 0.305 for Effort, both below the commonly cited 0.50 reference level. The corresponding composite reliability estimates, computed from the standardized loadings using the conventional construct-reliability formula, were approximately 0.817 and 0.810. This combination suggests acceptable composite reliability but insufficient convergent validity, consistent with the poor global model fit (Fornell & Larcker, 1981).

The standardized correlation between Mathematics Academic Confidence and Mathematics Academic Effort was 0.817 in the saved JASP results. The square roots of AVE were approximately 0.557 and 0.552, respectively, both lower than this factor correlation. Equivalently, the shared variance between factors ($r^2 = 0.667$) exceeded either AVE. The Fornell–Larcker criterion was thus not met, indicating insufficient discriminant validity in the current two-factor specification. This result does not by itself show that the factors are identical, but it raises concerns about their empirical distinctiveness.

Table 5a. Discriminant Validity Based on the Fornell–Larcker Criterion

| Factor | AVE | √AVE | Correlation (r) |
|---|---|---|---|
| Confidence | 0.310 | 0.557 | 0.817 |
| Effort | 0.305 | 0.552 | 0.817 |

### 3.3 Reliability Analysis

Reliability concerns the consistency of scores under a given measurement procedure. Cronbach's alpha provides an estimate of internal consistency, although it does not establish that an instrument measures the intended construct. Values around 0.70 are often used as a practical reference point, subject to the study context and purpose (Razaki, Ismail, & Anuar, 2023; Li & Lay, 2024).

Table 6. Reliability Mathematics Academic Self-Concept (MASC)

| | Coefficient α |
|---|---|
| Mathematics Academic Confidence | 0.778 |
| Mathematics Academic Effort | 0.756 |
| total | 0.853 |

Cronbach's alpha was 0.778 for Mathematics Academic Confidence, 0.756 for Mathematics Academic Effort, and 0.853 for the total scale as presented in the original manuscript (Table 6). The stored CFA output further reports reliability values, but these depend on the estimator and reliability definition and should not be conflated with the original alpha statistics. Composite reliability values computed from the standardized loadings were approximately 0.817 and 0.810.

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These findings support internal consistency but do not override the convergent- and discriminant-validity limitations.

The exact-fit test was significant ($p < 0.001$), contrary to the initial manuscript's interpretation of this result as acceptable fit. A significant chi-square indicates rejection of exact fit. Bartlett's test ($\chi^2 = 1959$, df = 190) concerns factorability rather than CFA model fit.

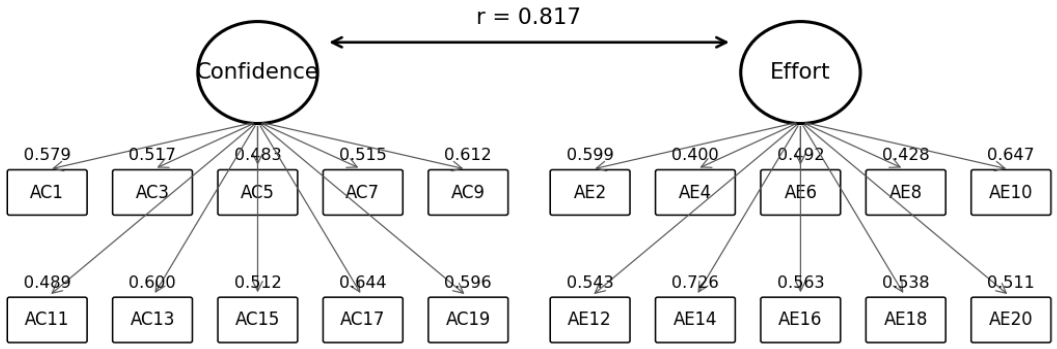
The model exhibited unfavorable values for several complementary indices (RMSEA = 0.154, CFI = 0.852, TLI = 0.833, SRMR = 0.121, NFI = 0.831, and IFI = 0.852). Although GFI was 0.935, interpreting this measure alone would overlook substantial misfit. The RMSEA confidence interval of approximately 0.145–0.162 further reinforces the concern. AGFI and $\chi^2$/df were not present in the saved CFA output. The model was intentionally left unmodified to report the original empirical findings, rather than introducing post hoc changes solely to improve numerical fit.

The findings also revealed important validity limitations. AVE was 0.310 for Confidence and 0.305 for Effort, suggesting that the factors did not explain a majority of their indicators' variance. The factor correlation ($r = 0.817$) exceeded both square roots of AVE (0.557 and 0.552), failing the Fornell–Larcker discriminant-validity criterion. Thus, even though the alpha and composite reliability estimates indicated internal consistency, the available CFA evidence did not support adequate convergent or discriminant validity for the proposed two-factor measurement structure.

The initial two-factor model was retained without post hoc modifications because the aim was to evaluate, rather than force acceptance of, the hypothesized structure. Modification indices in the JASP output may inform further investigation, but any future cross-loading or correlated error term would require a defensible substantive explanation and preferably confirmation with new data. Further studies should also document the translation and content-validation process in full. These limitations qualify the psychometric evidence presented here.

Figure 1. Hypothesized two-factor MASC structure with standardized loadings (schematic; factor correlation r = 0.817; residual arrows are not displayed).

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Standardized factor loadings; schematic, not a software-exported CFA path diagram

Taken together, the scale showed useful internal-consistency evidence, but fit indices, AVE, and the Fornell–Larcker comparison did not support the proposed two-factor structure adequately. The present findings are best interpreted as a critical evaluation of an adapted measure, rather than as confirmation that its construct validity has been established.

## 4. Conclusion

This study examined a mathematics-specific adaptation of the 20-item Academic Self-Concept scale among 252 senior high school students. The corrected item–rest correlations ranged from 0.299 to 0.616 and reflect associations with the remaining scale items, not item-fit statistics. KMO = 0.818 and a significant Bartlett's test indicated that the correlation matrix was suitable for factor analysis. Nevertheless, the unmodified two-factor CFA did not fit the observed data adequately: RMSEA = 0.154, CFI = 0.852, TLI = 0.833, SRMR = 0.121, NFI = 0.831, and IFI = 0.852, despite GFI = 0.935.

The confidence and effort subscales had AVE values of 0.310 and 0.305, respectively, while composite reliability was approximately 0.817 and 0.810. A latent factor correlation of 0.817 exceeded the square root of AVE for both factors, so the Fornell–Larcker discriminant-validity criterion was not met. Although the original alpha coefficients indicated adequate internal consistency (0.778 and 0.756; total 0.853), factorial, convergent, and discriminant validity were not established. The results therefore support further theory-informed development and independent evaluation of the scale rather than immediate use as a fully validated measure.

## 5. Aknowledgments

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