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Construct validity of a student mathematics learning style instrument using exploratory factor analysis

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Abstract.
This study seeks to validate the construction of mathematics learning style instruments for junior high school students using the Exploratory Factor Analysis (EFA) method. A total of 127 students from four schools in Central Lombok Regency, Indonesia, participated in this quantitative survey research. The instrument comprises 20 Likert scale statements designed to measure the various dimensions of a student's mathematics learning style. The feasibility test of the data revealed a Kaiser-Meyer-Olkin (KMO) value of 0.75, and the results of Bartlett's Test of Sphericity were significant ($p < 0.001$), indicating that the data was suitable for analysis using factor analysis. The results of the EFA employing the principal axis factoring and oblimin rotation methods yielded four primary factors: Visual Learning, Auditory Learning, Reading/Writing Style, and Kinesthetic Learning, which aligned with the VARK model. All items exhibited a dominant loading value of ≥ 0.51, with no significant cross-loading, suggesting a clean and well-defined factor structure. The balanced distribution of variance after rotation, coupled with theoretical suitability, supports the validity of the instrument's construction. These findings suggest that this instrument is appropriate for use in academic research and educational practice, enabling teachers to design differential learning strategies that cater to students' learning preferences, thereby enhancing engagement and learning outcomes.

Keywords:
Learning style; validity constructs; exploration factor analysis (EFA)

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INTRODUCTION

Education is a multifaceted process that encompasses a multitude of interrelated factors, each contributing to the attainment of optimal learning outcomes (Ahmad & Santosa, 2022; Grier, 2010; Khalid, 2024). One of the crucial factors influencing learning success is a student's learning style, which refers to an individual's inherent preference for acquiring, processing, and organizing information (Huber & Morreale, 2023). Learning styles can significantly impact students' comprehension of material, their interactions with instructors, and their ability to complete assignments. Consequently, educators must acknowledge these characteristics to design effective learning strategies (Li, 2022; Reid, 2005). The concept of learning style has been a subject of interest among education experts for an extended period, leading to the development of various models, including the Kolb model, the VARK (Visual, Auditory, Read/Write, Kinesthetic) model,

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and the Felder-Silverman model (Carvalho et al., 2020). Each model emphasizes a distinct dimension in identifying students' learning preferences. In the context of Indonesian education, cultural diversity, socioeconomic backgrounds, and learning environments contribute to the complexity of students' learning styles, necessitating accurate measurements that are pertinent to the local context (Joy & Kolb, 2009; Khaskhuu & Chimed-Ochir, 2023; Oxford & Gkonou, 2018).

Mathematics learning style measurement instruments serve as crucial tools for obtaining objective insights into students' learning preferences. Utilizing valid and reliable instruments, educators and researchers can identify specific patterns that subsequently inform the design of more targeted learning interventions (Helmiyatun, 2025; Hidayah et al., 2025). However, it is essential to acknowledge that not all instruments employed in the field have undergone adequate validation processes, particularly in terms of construction validity. Despite these limitations, Variety instruments style learn the used di field still exhibit certain drawbacks, particularly due to the absence of empirical testing and analysis factors to ensure that the structure of the items accurately represents the dimensions of learning style. These conditions pose methodological challenges that may lead to lower accuracy and misinterpretation of measurement results. Construct validity is a pivotal aspect of instrument development, as it determines the extent to which the instrument accurately measures the concept in question (Ahmad & Taqiudin, 2025; Kunwar et al., 2023). In the context of learning style instruments, construct validity ensures that the question items genuinely represent the hypothetical dimension of the learning style. Without robust construct validity, measurement results can be misleading, result in misinterpretation, and ultimately impact the effectiveness of the learning strategies employed (Fitriana & Supahar, 2019; Luo et al., 2018; Pandra et al., 2021).

One of the commonly employed statistical approaches for assessing construct validity is Exploratory Factor Analysis (EFA) (Ghani et al., 2022; Sürücü et al., 2024). This method enables researchers to discern the underlying factor structure of a set of items on an instrument, thereby determining whether the items are grouped according to a predetermined theoretical dimension. Additionally, EFA facilitates data simplification by identifying significant factors, resulting in a more concise and focused instrument (Mitchell, 2019; Nasidi et al., 2022). The significance of construct validation of the learning of mathematical style instrument construction extends beyond its academic relevance to its practical implications in the field (Hariono et al., 2020; Putri et al., 2022). Educators, school counselors, and education policymakers require accurate data regarding students' learning styles to make informed pedagogical decisions. Instruments that have undergone validity testing enable the solidification of decisions such as learning differentiation, adaptive curriculum development, and formative assessment strategies (Alahmadi et al., 2023; Imaduddin et al., 2022).

In the academic realm, research on the validity of instruments plays a pivotal role in the development of theories, particularly in comprehending the psychological structures that underpin individual variations in learning. Through construct validation, subsequent research can utilize the same instruments for comparative or longitudinal studies, thereby fortifying the empirical database on students' learning styles in Indonesia (Trejo-Mejía et al., 2016). Furthermore, the advancement of digital-based education and learning technology necessitates the adaptation of students' mathematics learning style instruments. Instruments developed in previous eras may no longer be fully pertinent to the contemporary learning environment, characterized by the increasing dominance of digital interaction and self-paced learning. Consequently, the revalidation of instruments is imperative to ensure their suitability within the context of modern learning. Urgency Validity becomes more pronounced when associated with measurement style. Learning styles constitute factors that significantly influence the manner in which students receive and process information. Therefore, teachers must recognize these characteristics to plan effective strategies. Remembering diversity culture and environment learning in Indonesia, Complexity learning styles students demand instruments measurement the instrument must not only be valid by theoretical standards but also relevant to the local context. Valid instruments enable teachers and researchers to gain an overview of the objectives for planning interventions and to precisely identify the target.

In contrast, Field's reality di field show presence gaps the significant in process development instruments. Overview literature and observations di field indicates that many instruments style learn the used moment ini not yet through process validation the squirt, in particular validity construction. Often, Instruments only adopted direct from models' foreigners without test empirical the deep against structure the factors, or researcher using questionnaire the already there without documents supporters the show evidence validity the clear (Alzain et al., 2018). Absence evidence validity in risky produce biased data and interpretation the misleading about preferences learns students. For overcoming problems, the, required approach statistics the strong for test validity instruments. False one method the precise is Exploratory Factor Analysis (EFA). The EFA method is a good choice in the early stages of validation due to its exploratory nature, allowing researchers to find patterns of factors that may differ from the initial hypothesis (Wusqo et al., 2022). This is especially important given the diverse characteristics of students, which can give rise to unique factor structures in a particular educational context. Thus, research on the validation of learning style instrument construction using EFA is expected to provide benefits not only for the development of the instrument itself, but also for more evidence-based educational practices. Valid data will help education practitioners make interventions that truly meet students' needs, increase motivation, and ultimately improve learning outcomes (Shrotryia & Dhanda, 2019).

Previous research has demonstrated the effectiveness of using usage method statistics to guarantee the quality of educational instruments. As evidenced by Azman Ong et al. (2022) and Ghazali et al. (2021), exploratory factor analysis (EFA) has proven capable of producing structure factors with consistent and high reliability (Cronbach's Alpha > 0.70) in the context of online learning and MOOCs. These findings affirm that instruments validated by construction possess strong validity, nomological, and discriminatory properties, making them suitable for basic evaluation purposes.

In contrast, focus validation, the majority research style, learns at a basic school level, such as the work done by Rahmatika et al. (2024) and Singh et al. (2015). Stuttgart directly focuses on mapping students' preferences (such as dominance style, visual, or auditory) without specifically discussing the deep process validation tools used. This matter shows that usage instruments are often accepted without testing and repetition.

Although numerous instruments styles are used in Indonesia, only a limited number of Stuttgart models are directly adopted without adaptation and empirical testing in diverse local contexts (Khaskhuu & Chimed-Ochir, 2023). This gap is more pronounced with minimal research utilizing method analysis factors for testing the structure construction of instruments styles at the school medium level. Nevertheless, Exploratory Factor Analysis (EFA) is crucial at this stage to ensure that the theory used is truly compatible with empirical data in the field (Sürücü et al., 2024).

Inaccuracies in identifying students' mathematical learning styles can have detrimental effects on learning planning (Carvalho et al., 2020). For instance, educators may implement strategies that do not align with the majority of students' learning preferences within their classrooms, leading to diminished learning efficacy. This underscores the significance of addressing gaps in instrument validation, as they can significantly impact the overall quality of education. Consequently, it is imperative to conduct research that specifically evaluates the validity of the construction of student learning style instruments using appropriate methodologies and representative empirical data. This research is anticipated to rectify these gaps and produce a valid instrument that is poised for widespread adoption.

This study seeks to ascertain the validity of the construction of students' mathematical learning style instruments employing the Exploratory Factor Analysis (EFA) methodology. Through this analysis, it is anticipated to discern the number of factors underlying the instrument, ascertain the appropriateness of the items with the identified factors, and evaluate the suitability of the items for continued use or elimination. This research centers on a learning style instrument comprising 20 items designed to assess various dimensions of learning preferences among junior high school students and/or their equivalent. This study exclusively addresses the validity aspect of the construction utilizing the EFA method, thereby excluding other validity dimensions such as content validity and criterion validity from its primary focus. Nevertheless, the findings of this study could serve as a foundation for further research investigating these validity dimensions.

METHOD

This quantitative research study employs a survey approach to collect numerical data from respondents through questionnaires. These questionnaires are subsequently subjected to statistical analysis. This methodology was selected due to its suitability in identifying the structure of the underlying factors of the student's mathematical learning style instrument items. This enables the empirical testing of the construct's validity (Mathieu et al., 2020). Exploratory Factor Analysis (EFA) is utilized to explore and validate the latent dimensions comprising the concepts of students' mathematical learning styles. This process facilitates the development of high-quality instruments for research and educational practice. The study involved 127 junior high school students who were randomly selected from four schools/madrasas in Central Lombok Regency, Indonesia. The respondents comprised students in grades VII to IX, aged between 12 and 16 years. These students exhibited diverse socioeconomic backgrounds and academic achievements. The instrument employed was a student mathematics learning style questionnaire comprising 20 statements, each rated on a Likert scale ranging from 1 to 5. The questionnaire was based on the VARK learning style model developed by Fleming and Mills (1992). The theory underpinning the questionnaire's preparation is the VARK learning style model.

Data was collected through the completion of questionnaires directly in the classroom, facilitated by researchers and subject teachers. This approach ensured that respondents comprehended each statement item. Data analysis was conducted using Exploratory Factor Analysis (EFA) to elucidate the structure of the underlying factors of students' mathematical learning style instruments. Prior to conducting EFA, data feasibility testing was performed using the Kaiser-Meyer-Olkin Size Adequacy of Sampling (UKM) and Bartlett's Sphericity Test. These tests were conducted with subject matter experts (SMEs) and Bartlett's Test to ascertain the suitability of the data for analysis using factor analysis. The Kaiser-Meyer-Olkin (KMO) assesses the adequacy of the sample and the relationships between variables, determining whether they are sufficiently strong to form a factor. The SME Value utilized for assessing sufficiency is presented in Table 1.

Table 1. The SME values

SME Value	Criteria Interpretation
≥ 0.90	Categorized as very good
0.80–0.89	Categorized as good
0.70–0.79	Categorized as enough (medium)
0.60–0.69	Categorized as moderate
< 0.60	Categorized as no

If the SME Value is less than 0.60, the data is not suitable for analysis using factor analysis (Kaiser, 1974). The Bartlett test evaluates whether the correlation matrix exhibits a statistically significant deviation from the identity matrix (Artola et al., 2020). If both criteria are met, the data is deemed suitable for Exploratory Factor Analysis (EFA). The process involves extracting factors using the main factoring method with oblimin rotation, ensuring that these factors exhibit correlations. The selection of this analysis method aims to provide a comprehensive understanding of the instrument's validity, enabling readers to evaluate the reliability and validity of the research findings and draw conclusions based on robust empirical evidence.

RESULTS AND DISCUSSION

Data Eligibility for Factor Analysis (UKM & Bartlett)

Data feasibility testing is conducted to ascertain that the data collected fulfills the prerequisites for the application of Exploratory Factor Analysis (EFA). Table 2 presents the

Kaiser-Meyer-Olkin (KMO) value of 0.75, which falls within the intermediate range according to the Kaiser classification. This value suggests that a substantial portion of the data variance can be attributed to latent factors, rendering factor analysis a viable approach. Additionally, the Bartlett Specificity Test yielded a Chi-square value of 800.3883 with degrees of freedom (df) = 190 and a significance level of $p < 0.001$. The findings of this study indicate that the correlation matrix between instrument items exhibits a significant deviation from the identity matrix, implying sufficient correlation between variables to warrant further analysis through Exploratory Factor Analysis (EFA).

Table 2. Analysis results of SMEs and Bartlett

Tests	Value	Df	Sig.	Interpretation
Kaiser-Meyer-Olkin (KMO)	0.75	–	–	Sufficient for factor analysis (intermediate category)
Bartlett's Sphericity Test	800.3883	190	< 0.001	Significant and feasible data for factor analysis

An SME value of 0.75 signifies that the data quality is sufficient for factor analysis, aligning with the recommended standards. Kaiser (1974) categorizes the value of Small and Medium Enterprises (SMEs) between 0.70 and 0.79 as a category of Medium. This value suggests a strong correlation between the variables and a sufficient sample size of 127 students to produce a stable estimation of factors. Several instrument validation studies, including those conducted by Isma'il and Sodangi (2025) and Abdollahimohammad and Ja'afar (2014), have reported UKM scores within the acceptable range of 0.70-0.80 as an indicator in psychometric studies. The Bartlett Sphericity Test results ($p < 0.001$) further substantiate this finding by demonstrating a high correlation between items, which is sufficient for factor extraction.

Methodologically, the combination of adequate SME values and significant Bartlett results serves as a solid foundation for proceeding with the factor extraction stage. In the context of this study, the findings support the purpose of validating the construction of students' mathematical learning style instruments through Exploratory Factor Analysis (EFA), ensuring that the results obtained are scientifically substantiated and have practical application value in the field of education. Consequently, based on the results of this feasibility test, the analysis of exploratory factors conducted on the students' mathematical learning style instruments is believed to provide an accurate representation of the structure of the dimensions measured, thereby contributing to the development of valid and reliable instruments for use in research and learning practices.

Structure of Factors Found (Eigenvalue, Scree Plot, Variance)

Based on the analysis of exploration factors, four primary factors were identified that met the self-value criteria of ≥ 1. Each factor demonstrated a substantial contribution in elucidating the total variance of the instruments measuring students' mathematical learning styles. The eigenvalue values, proportions of variance, and cumulative variance are presented in detail to provide an overview of the contribution distribution of each factor to the measured construct. The following table summarizes the results of these calculations, both before and after rotation, facilitating the interpretation of the structure of the factors that are formed. These findings serve as the foundation for determining the latent dimensions of valid and reliable instruments. Table 3 presents the results of the exploration factor analysis, which identify four primary factors that meet the ≥ 1 value criterion. This finding is corroborated by Figure 1, which depicts the scree plot.

Table 3 presents the eigenvalues of the factors, which explain the variance before and after rotation. The first factor has an eigenvalue of 3.7019, accounting for 13.3% of the variance before rotation and 29.3% after rotation. The second factor has an eigenvalue of 2.9243, explaining 11.3% of the variance before rotation and 25.0% after rotation. The third factor, with an eigenvalue of 2.5072, explains 11.1% of the variance before rotation and 24.4% after rotation. The fourth factor, with an eigenvalue of 2.0834, contributes 9.6% of the variance before rotation and 21.2% after rotation. Cumulatively, these four factors account for 45.3% of the variance before rotation and increase significantly to 100% of the variance after rotation. This indicates that all instrument items are perfectly distributed into the four latent factors formed. The even distribution of variance after rotation demonstrates the balance of contributions between factors to the structure of the construction of the students' mathematics learning style instruments.

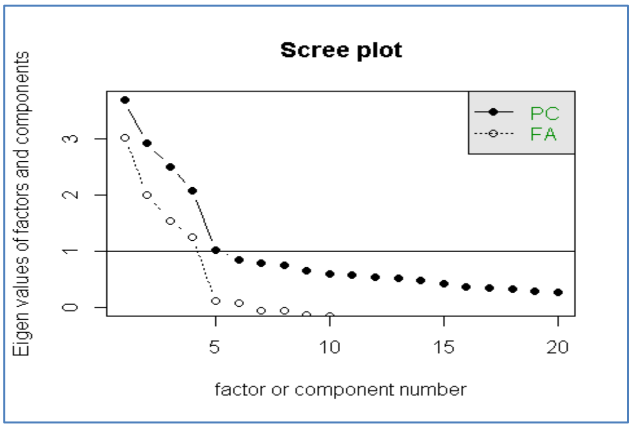

Figure 1. Scree plot PCA

Figure 1 (Scree Plot PCA) corroborates the findings of the exploratory factor analysis presented in Table 3. The scree plot exhibits a pronounced decline in eigenvalue from the first factor to the fourth factor, followed by a relatively flat line from the fifth factor onward. This pattern reveals a distinct elbow point in the fourth factor, signifying that only four factors contribute significantly to the variance in the instrument construction. Factors beyond the fourth factor exhibit an eigenvalue below or close to 1 and a minimal variance contribution, rendering them unsuitable for further consideration. Consequently, based on the scree plot criteria and Kaiser's criteria (eigenvalue ≥ 1), the optimal number of factors to represent the latent structure of the student's mathematical learning style instruments is four factors. These findings demonstrate a strong consistency between the results of the eigenvalue table and the scree plot visualization, thereby reinforcing the validity of the constructed instrument.

Table 3. Eigenvalues, proportions of variance, and cumulative variance

Factors	SS Loading	Own value	Proportion of Variance	Cumulative Variance	Proportions Explained	Cumulative Proportions
1	2,656	3,7019	0,133	0,133	0,293	0,293
2	2,267	2,9243	0,113	0,246	0,250	0,543
3	2,212	2,5072	0,111	0,357	0,244	0,788
4	1,923	2,0834	0,096	0,453	0,212	1,000

The results of this study indicate that the students' mathematics learning style instruments possess a robust factor structure with four distinct latent dimensions. An eigenvalue exceeding 1 signifies that each factor contributes significantly to the total variance, as per Kaiser's (1960) criteria. The observation that the first factor exhibits the most substantial contribution aligns with the principle of first factor dominance in factor analysis, wherein the initial factor typically encompasses the largest data variance. The increase in the proportion of variance from 45.3% to 100% following varimax rotation suggests that the rotation technique effectively distributes the variance evenly among the factors, facilitating conceptual interpretation. This is of paramount importance in the development of the instrument, as the balanced distribution of variants enables all factors to attain proportional weights in elucidating the construct being measured.

Theoretically, the presence of these four factors aligns with the framework of students' mathematical learning styles, which distinguishes the cognitive, affective, and learning preferences dimensions of students. These findings are also consistent with research conducted by Abdollahimohammad and Ja'afar (2014) and Baig and Ahmad (2016), which demonstrated that a valid student's mathematical learning style instrument typically possesses more than one latent dimension with a stable factor structure. Consequently, the factor structure obtained in this study not only meets statistical criteria but also exhibits conceptual congruence with the mathematical learning style theory employed, thereby supporting the instrument's validity for use in the context of junior high school students.

Loading Factors and Item Grouping

The analysis of the dominant loading factors for each instrument item reveals the variation in the strength of the relationship between the item and the factors it represents. A high loading value signifies the item's substantial contribution to factor construction. The four factors identified as Auditory Learning, Kinesthetic Learning, Reading/Writing Style, and Visual Learning exhibited a relatively even distribution of loading values. The accompanying Tables 4 and 5 provide a visual representation of the loading values for each item, facilitating the assessment of the consistency and relevance of the indicators to the measured latent dimensions.

Table 4. Summary of factors

	Factor1	Factor2	Factor3	Factor4
SS Loading	2.656	2.267	2.212	1.923
Var Proportions	0.133	0.113	0.111	0.096
Cumulative Var	0.133	0.246	0.357	0.453
Proportions Explained	0.293	0.250	0.244	0.212
Cumulative Proportions	0.293	0.543	0.788	1.000

Based on the analysis of exploration factors (EFA) 20 in Table 4 of the statement of students' mathematical learning style instruments, four main factors that meet the criteria are identified. These factors have an Eigenvalue (λ) greater than or equal to 1, as recommended by Gal et al. (2020) and Kaiser (1960). The four factors have the following Eigenvalues: Factor 1: 2,656, Factor 2: 2,267, Factor 3: 2,212, and Factor 4: 1,923. Before rotation, the first factor explains 13.3% of the total variance, the second factor 11.3%, the third factor 11.1%, and the fourth factor 9.6%. Cumulatively, these four factors account for 45.3% of the variance of the instruments. After rotation, the proportion of variance described becomes more even. Factor 1 accounts for 29.3%, Factor 2 for 25.0%, Factor 3 for 24.4%, and Factor 4 for 21.2%, making a total contribution of 100%. This balanced distribution demonstrates the success of the rotation process in distributing variance among factors, facilitating interpretation and reducing the dominance of the first factor.

Table 5 presents a pattern matrix analysis that reveals a distinct factor structure. Each item exhibits a dominant loading value of ≥ 0.51 on a specific factor, while the absence of significant cross-loading (> 0.30 on two factors) suggests a clean and well-defined factor structure.

Factor 1 comprises five items (Item_16-Item_20) that collectively measure the Reading/Writing Style dimension. Notably, Item_16 demonstrates the highest loading value at 0.766, while Item_20 exhibits the lowest at 0.722. The similarity value (h^2) of this factor ranges from 0.457 to 0.596, indicating a substantial contribution of each item to the factor formed.

Factor 2 encompasses five items (Item_6-Item_10) that represent Auditory Learning. The highest loading values are observed at Item_7 (0.723) and Item_6 (0.580), while the lowest are at Item_10 (0.551). The similarity value (h^2) of this factor ranges from 0.364 to 0.551.

Factor 3 comprises five items (Item_11-Item_15) that represent Kinesthetic Learning. The highest loading values are observed at Item_15 (0.717) and Item_12 (0.559), while the lowest are at Item_11 (0.540). The similarity value (h^2) of this factor ranges from 0.364 to 0.551.

Factor 4 comprises five items (Item_1-Item_5) that measure Visual Learning. The highest loading values are observed at Item_1 (0.638) and Item_2 (0.518), while the lowest are at Item_5 (0.492). The similarity value (h^2) of this factor ranges from 0.364 to 0.551.

The overall similarity value ranges from 0.278 to 0.596. The lowest value was observed at Item_2 (0.278), indicating that a significant portion of the variance is not accounted for by the factors being considered. Conversely, the highest value at Item_16 (0.596) suggests that more than half of the item's variance can be explained by relevant factors. A high uniqueness value (u^2), as seen in Item_2 (0.722), implies the necessity of evaluating the item at the subsequent stage of instrument development, as its contribution to the construction is relatively modest. Conversely, a low u^2 value, such as in Item_16 (0.404), indicates that the item exhibits a favorable alignment with the factor it represents.

Table 5. Standard loading (pattern matrix) based on correlation matrix

Item	Factor1	Factor2	Factor3	Factor4	h^2	u^2	Com
Item_1				0.638	0.424	0.576	1.08
Item_2				0.518	0.278	0.722	1.07
Item_3				0.604	0.396	0.604	1.17
Item_4				0.628	0.400	0.600	1.03
Item_5				0.583	0.376	0.624	1.22
Item_6		0.580			0.364	0.636	1.17
Item_7		0.723			0.551	0.449	1.11
Item_8		0.632			0.497	0.503	1.48
Item_9		0.619			0.397	0.603	1.08
Item_10		0.715			0.526	0.474	1.06
Item_11			0.693		0.504	0.496	1.10
Item_12			0.559		0.334	0.666	1.14
Item_13			0.625		0.421	0.579	1.15
Item_14			0.619		0.415	0.585	1.17
Item_15			0.717		0.523	0.477	1.04
Item_16	0.766				0.596	0.404	1.03
Item_17	0.688				0.498	0.502	1.10
Item_18	0.707				0.568	0.432	1.28
Item_19	0.638				0.457	0.543	1.25
Item_20	0.722				0.533	0.467	1.04

These results demonstrate strong internal consistency across each factor, characterized by relatively high loading values and homogeneity within a single factor. The absence of significant cross-loading suggests that each item primarily measures a single dimension. Theoretically, this factor division aligns with the VARK (Visual, Auditory, Reading/Writing, Kinesthetic) model proposed by Fleming & Mills (1992), which maps students' learning styles based on the primary modalities used for information processing. These findings also corroborate research by Lujan & Dicarlo (2006) and Hawk & Shah (2007), which reported that students' learning preferences at the secondary education level tend to be distinctly categorized into these four modalities.

From a practical standpoint, these results hold significant implications for the learning process. Teachers can utilize information regarding the distribution of students' learning styles to design appropriate differential learning strategies. For instance, students with visual learning styles will be more effective when presented with material through visual aids such as pictures, diagrams, and learning videos; auditory learners require oral instruction and group discussions; kinesthetic learners will benefit from hands-on activities; and students with a reading/writing learning style will gain from the provision of text materials, notes, and writing exercises. With valid learning style mapping, teachers can design a more adaptive and inclusive learning experience, thereby enhancing student engagement and overall learning outcomes.

Methodologically, the validity of the construct confirmed through Exploratory Factor Analysis (EFA) provides assurance that the instrument is suitable for use in both academic research and practical applications. The clear factor structure, high loading values, and even distribution of variance support the conclusion that this instrument accurately measures the dimensions of students' mathematical learning styles. These findings can serve as a foundation for further research, including examining the relationship between mathematics learning styles and students' mathematics learning outcomes, developing adaptive learning modules, and evaluating the effectiveness of learning style-based teaching strategies across various educational levels.

CONCLUSION

This study successfully validated the construction of mathematics learning style instruments for junior high school/MTs students using the Exploratory Factor Analysis (EFA) method. The results of the analysis demonstrated a value of SME of 0.75 and a significant Bartlett test ($p < 0.001$), indicating that the data was suitable for factor analysis. The EFA generated four main factors that aligned with the VARK model (Visual Learning, Auditory Learning, Reading/Writing Style, and Kinesthetic Learning) with a clean factor loading distribution and no significant cross-loading. The clear structure of the factor, the contribution of even variance after rotation, as well as theoretical consistency with the existing learning style framework, substantiate that this instrument is constructively valid and can be utilized for academic research and learning practice. In practical terms, these findings provide a basis for teachers to design differential learning strategies that cater to students' learning preferences, thereby enhancing engagement and learning outcomes. However, this study has limitations, primarily that the instrument testing is solely focused on the validity of the construction using EFA with a limited number and scope of samples from one region. Therefore, further research is recommended to confirm the structure of the factor using Confirmatory Factor Analysis (CFA), expand the number and characteristics of the sample, and test the aspects of other validities such as criterion validity and advanced reliability to strengthen the quality and generalization of the instrument.

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