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Measuring learning styles in mathematics: A validity and reliability study

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Abstract

Background: Learning style is one of the factors that can facilitate students in understanding subject matter, especially mathematics. Learning style is related to how students absorb and process mathematical concepts optimally. This has a direct impact on improving student learning outcomes. Therefore, teachers need to design learning activities that are in line with students' learning style tendencies. Thus, a valid and reliable learning style scale instrument is needed.
Aim: This study aims to develop a valid and reliable measurement scale instrument to identify the learning style of junior high school students in learning mathematics.
Method: This research is measurement scale development research. The respondents of this study totalled 184 students. The content validity test used the Aiken V index formula, while the construct validity used factor analysis. Reliability test used Cronbach alpha test
Result: The results of this study indicate that: (1) the developed instrument meets the validity criteria based on Aiken's V analysis and factor analysis; and (2) the instrument also meets the reliability criteria based on the results of Cronbach's alpha analysis. The instrument consists of 6 statements to measure visual learning style, 5 statements for auditory, and 7 statements for kinesthetic.
Conclusion: learning style scale has met the criteria of valid and reliable with three factors namely visual, auditory and kinesthetic. These findings can be used by teachers to diagnose students' learning style tendencies as a basis for designing mathematics learning, as well as developing similar scales in different subject contexts.

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INTRODUCTION

One of the factors that influence the success of student learning is the ability to understand information well on the material studied (Saeed & Zyngier, 2012). Good understanding will make it easier for students to achieve optimal learning outcomes, including in learning mathematics. In general, students' difficulty in understanding mathematical concepts is due to insufficient prior knowledge as a basis for mastering the concepts to be learned (Wakhata et al., 2023). In addition, there are three main factors that also influence student learning success, namely cognitive, affective, and environmental factors (Zeichner, 2018). Cognitive factors include logical thinking skills, understanding concepts, and problem-solving skills all of which are fundamental to learning mathematics (Abdullah et al., 2020; Sheromova et al., 2020). Affective factors include student attitude, interests, motivation, and self-confidence towards mathematics. Students who are highly motivated and have a positive attitude towards mathematics tend to be more active in the learning process (Ampadu & Anokye-Poku, 2022; Muanifah et al., 2019; Sholihah, 2022;). Meanwhile,

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environmental factors include the learning atmosphere, the role of teachers, the availability of learning media, and support from parents and peers (Tay et al., 2021) A supportive learning environment will strengthen motivation and facilitate students' learning activities to the fullest.

These three factors are interrelated and form a holistic learning experience. However, to practically connect these three aspects in learning, learning style becomes a key variable that needs to be considered. With learning styles, the potential of cognitive and affective factors can increase, and the learning environment becomes more innovative and meaningful (Andrade-Arenas et al., 2023). This is because learning styles play an important role in receiving and processing information (Shaidullina et al., 2023), and are influenced by cognitive factors (ways of thinking and processing information), affective factors (interest and attitude towards learning), and environmental factors (teaching methods, media, and learning experiences).

When students learning styles are not accommodated in the learning process, they may struggle to understand mathematical concepts, even if they possess good cognitive potential. Conversely, when teachers can adapt learning strategies, methods, or media to students' learning styles, the learning experience becomes more meaningful and enjoyable, positively impacting learning interest, facilitating student ability to receive and process information, and thereby influencing improvements in students' mathematical learning outcomes. Therefore, learning style factors need to be considered so that students' learning experiences become more comprehensive (Maya et al., 2021).

Learning style is a way of learning from each student that can affect memory and understanding of the material learned (Li et al., 2016). By knowing students' learning styles, teachers can provide learning methods that can accommodate the diverse learning styles of each student (Dong et al., 2019). This can make information processing more effective, so it tends to make it easier for students to understand the concepts presented, as well as creating an inclusive and fun learning environment (El-Sabagh, 2021). Gardner (1983), through his theory of Multiple Intelligences, states that each individual possesses a combination of linguistic, logical-mathematical, spatial, kinesthetic, musical, interpersonal, intrapersonal, naturalistic, and existential intelligences. These intelligences influence students in receiving and processing information. Therefore, there is a tendency for certain learning styles as a way for students to receive information. Students with kinesthetic intelligence tend to prefer hands-on learning experiences (practical activities). Similarly, students with spatial, verbal, or musical intelligence will choose learning activities involving audio-visual materials, images, reading, or writing. Furthermore, Fleming and Mills (1992) define learning styles as individual preferences in how they gather, organize, and understand information. The main concept in this learning style is the sensory modality in receiving information. Thus, Gardner, as well as Fleming and Mills, focus on the use of appropriate learning media according to the learning style.

Meanwhile, Kolb states that learning styles are the ways individuals process information through the stages of learning experience, namely concrete, reflection, conceptualisation, and experimentation (Manolis et al., 2013). Learning styles are formed from the interaction between how someone captures experiences (Concrete Experience or Abstract Conceptualisation) and how they process them (Reflective Observation or Active Experimentation). This implicitly suggests that effective learning occurs when learning media can be designed differently according to each stage of the learning cycle, as each stage reflects a different way of receiving and processing information. In other words, the use of media should be tailored to the characteristics of each stage of the learning process.

There are several types of learning styles. This research focuses on 3 types of learning styles, namely visual, auditory and kinesthetic. Visual learning style is a person's tendency to learn through vision. People with this learning style find it easier to understand and remember information when it is presented in the form of pictures, diagrams or graphs (Smith & Brown, 2021). Auditory learning style is a person's tendency to learn through vision. People with this learning style are better at understanding and remembering information through discussions, listening to explanations, or the use of music (Williams, & Davis, 2023). Kinesthetic learning style is a person's tendency to learn through physical movement. People with this learning style understand information better through doing, lab work, or physical activity (Nguyen & Patel, 2024).

In learning mathematics, teachers need to understand their students' learning styles, before designing instructional designs. Based on several studies, there are several implications, namely increasing student understanding and engagement in learning (Maamin et.al., 2021), improving mathematical problem-solving skills (Kaitera & Harmoinen, 2022), and increasing academic achievement (Bayarcal & Tan, 2023). Therefore, students' learning styles need to be identified from the beginning before the implementation of learning through a scale instrument.

Based on previous research, a valid and reliable learning style questionnaire instrument has been developed. However, the learning style questionnaire developed is still limited to content validity and reliability. Nizaruddin et al., (2020) developed a learning style questionnaire based on an adaptation of the Victoria Chislett & Alan Chapman model with three types of learning styles, namely visual, auditory, and kinesthetic. This instrument was tested using Product Moment correlation and Cronbach Alpha, and was used to measure learning styles in general. Ardyani et al., (2021) also developed a similar instrument with the three learning style types and tested its validity using the Aiken index, Product Moment correlation, and Cronbach Alpha. Meanwhile, Astuti et al., (2023) further adapted the Chislett & Chapman model by tailoring it to the context of mathematics learning, using the same testing methods, so that the developed instrument could measure learning styles in mathematics learning.

Unlike previous studies, this research presents novelty through the synthesis of various learning style theories from DePorter & Hernacki (1992), Fleming & Baume (2006), Othman & Amiruddin (2010), and Wiedarti (2018), which were then specifically contextualised for mathematics learning. Additionally, this study not only uses the Aiken index and Cronbach's Alpha test but also applies factor analysis to strengthen the construct structure of the instrument. As a result, the questionnaire produced is not only valid and reliable but also has a more comprehensive and relevant measurement capability to describe students' learning styles in the context of mathematics learning. The purpose of this study was to develop a learning style scale that meets the criteria of validity and practicality for mathematics learning.

METHOD

Research Design

This research is a measurement scale development research. The instrument developed is a learning style measurement scale in learning mathematics. This method was chosen because it is specifically designed to build psychometric instruments, and is able to ensure that the scales developed have adequate validity and reliability. In addition, learning style is a latent psychological construct that cannot be measured directly, so it requires a measurement scale that contains clearly defined and measurable indicators.

The development procedure consists of four stages, including (1) Defining and Specifying the Construct Being Measured; (2) Generating an Item Pool; (3) Providing and Considering the Study of Experts on the Initial Item Pool; and (4) Refining and Validating the Scale; and (5) Finalising the Scale (Clark & Watson, 2019; DeVellis, 2017). An explanation of this development procedure is presented in Figure 1.

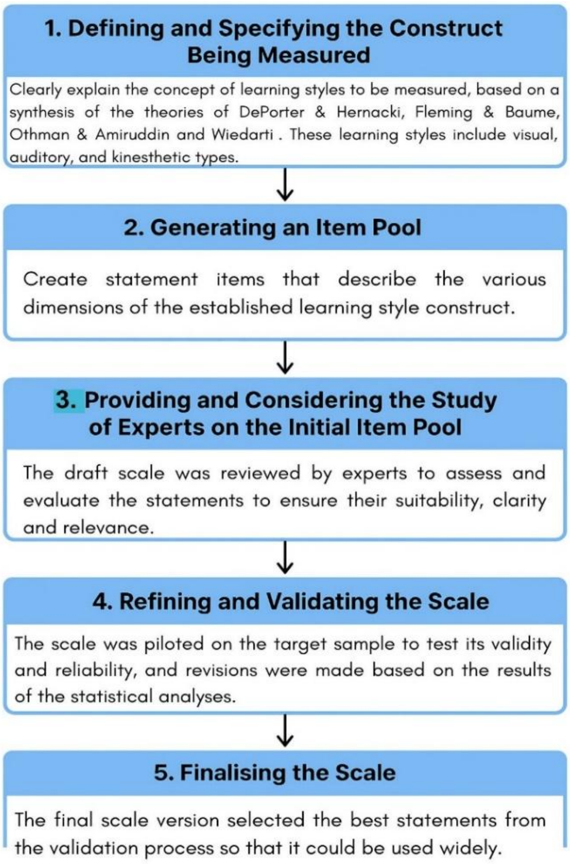

Figure 1. Development Procedure

Participant

The data for this study were collected from two private junior high schools in Yogyakarta, Indonesia. There were 184 students sampled in this study. The sampling used convenience sampling technique (Huck, 2012). Researchers can select respondents based on their access, convenience and affordability. This technique is used for initial trials in the development of measurement scales (DeVellis, 2017). In addition, to ensure that the analysis of construct validity and reliability gets accurate and consistent results, the sample size taken has fulfilled the element of sufficiency, which is more than five times the number of items (Hair et al., 2010).

Instruments

The learning style measurement scale was developed in the form of a questionnaire. There are 3 aspects of learning styles in the developed questionnaire, namely visual, auditory and kinesthetic. A total of eight statement items for each type of visual, auditory, and kinesthetic learning style in this instrument were developed based on the results of synthesis and construction of learning style theories, aspects, and indicators. The synthesis process refers to the concepts proposed by DePorter & Hernacki (1992), Fleming & Baume (2006), Othman & Amiruddin (2010), and Wiedarti (2018), so that each item reflects the distinctive characteristics of each learning style.

This questionnaire is in the form of a Likert scale with 5 answer options starting from 1 (strongly disagree) to 5 (strongly agree). After the instrument was developed, the first stage was testing the content validity of the instrument. This test involved four experts in the field of mathematics education. Expert feedback included an assessment of the suitability of the construction of statement items and indicators, as well as the use of good, effective, and communicative grammar The next stage, the instrument was trialled to respondents whose results were used to measure its construct validity and reliability. Meanwhile, revisions after the pilot test were carried out by considering items that showed a good level of validity.

Data Analysis

Data analysis in this study includes validity and reliability analysis. The validity aspect includes analysis of the results of content validity and construct validity. Content validity was calculated using the Aiken index formula. While construct validity uses factor analysis. The scale development method emphasises the constructs on the dimensions of the developed scale. Factor analysis is used with the aim of ensuring that the items in the scale are in accordance with the indicators or dimensions of the theory that has been synthesised after previously obtaining an assessment and evaluation from experts on the validity of the content of the developed scale. The steps of factor analysis, first determining the Kaiser-Meyer-Olkin (KMO) with test criteria greater than 0.5 (Lorenzo-Seva & Ferrando, 2021). Next, perform the Bartlett test with the criteria if the sig value <0.5. The next step is the anti-image correlation (AIC) test with criteria greater than 0.5. Finally, determine the loading factor (LF) value in the component matrix section, with the test criteria for the loading factor value> 0.4 (N = 184).

While the reliability test uses Cronbach alpha. This test aims to test an instrument whether it can provide consistent results when reused under the same conditions (Mohamad et al., 2015). For the Cronbach alpha test, if the value is above 0.6, the instrument has met the reliability criteria (Taber, 2018).

RESULTS AND DISCUSSION

Defining and Specifying the Construct Being Measured

This stage is the initial process to define the conceptual framework of the learning style scale to be developed. This learning style scale is focused on the context of learning mathematics (Learning Style Scale for Mathematics Education/LSS-ME). The conceptual framework of the LSS-ME was synthesised based on the concepts of learning style theory that have been studied previously (DePorter & Hernacki, 1992; Fleming & Baume, 2006; Othman & Amiruddin, 2010; Wiedarti, 2018). It resulted in three learning style constructs that became aspects in the development of this scale. The LSS-ME conceptual framework includes visual, auditory and kinesthetic learning styles. The three learning styles are the constituent factors of the scale. The LSS-ME conceptual framework is presented in Figure 2.

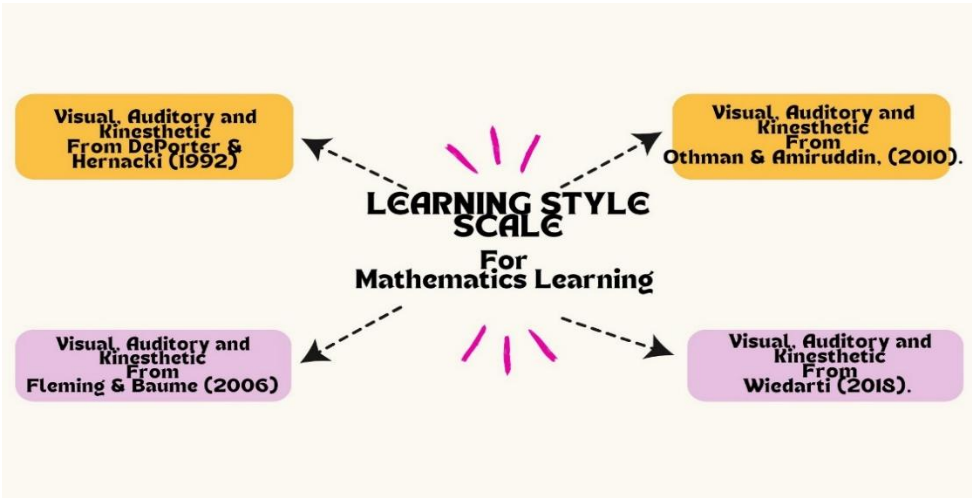

Figure 2. Theoretical Framework of LSC-ME

Generating an Item Pool

The theoretical framework of LSS-ME produces 3 factors which include visual, auditory and kinesthetic learning styles. Thus, at this stage constructing items that can measure these factors. In other words, items in the form of statements related to aspects of the three learning styles. A construction of 24 items was obtained, with each factor totaling eight items. The list of statements is presented in Table 1.

Table 1. Factor and Statement (English-Indonesian Version)

Factor	Statement (Indonesian- English Version)
Visual	(V1) Saat belajar matematika di kelas, saya lebih mudah mengingat dengan cara melihat gambar, diagram, maupun grafik (*When learning maths in class, I find it easier to remember by looking at pictures, diagrams and graphs*) (V2) Saya merasa sulit ketika memahami materi matematika, jika penyajiannya menggunakan gambar, diagram maupun grafik (*I find it difficult to understand maths material if it is presented using pictures, diagrams or graphs*.) (V3) Saya lebih suka mencatat materi matematika dalam bentuk gambar, grafik agar mudah dipahami dan diingat (*I prefer to record mathematics material in the form of pictures, graphs so that it is easy to understand and remember*) (V4) Saya sulit menyajikan jawaban dari soal matematika ke dalam bentuk gambar dan grafik (*I find it difficult to present answers to maths problems in the form of pictures and graphs*.) (V5) Saya sulit memahami materi matematika yang hanya disajikan dalam bentuk tulisan (*I find it difficult to understand mathematics material that is only presented in written form*) (V6) Ketika guru menjelaskan materi matematika, saya mampu mencatatnya dengan baik (*When the teacher explains the maths material, I am able to take good notes*.) *(V7)* Saya lebih suka dengan pertanyaan yang jawabannya ya atau tidak (I *prefer questions with yes or no answers}* (V8) Saya cendrung sulit untuk memberikan penjelasan yang detail ketika diberi pertanyaan matematika oleh guru (*I tend to find it difficult to give detailed explanations when asked maths questions by my teacher*).
Auditory	(A1) Saya lebih dapat mengingat dan memahami materi pelajaran matematika setelah mendengar penjelasan oleh guru (*I am better able to remember and understand the maths material after listening to the teacher's explanation*). (A2) Saya mudah dalam memahami materi matematika melaui video pembelajaran (*I find it easy to understand maths material through learning videos*) (A3) Ketika berdiskusi Pelajaran matematika di kelas, saya selalu berbicara dengan lancar dan tidak gugup (*When discussing maths lessons in class, I always speak fluently and am not nervous*) (A4) Saya merasa kesulitan untuk berbicara atau menyampaikan materi matematika ketika sedang presentasi didepan kelas (*I find it difficult to speak or convey mathematics material when presenting in front of the class.*) (A5) Saya lebih mudah memahami materi matematika ketika saya membaca dengan bersuara (*I find it easier to understand maths material when I read aloud*) (A6) Saya lebih suka membaca buku matematika dengan suara yang keras (*I prefer to read maths books out loud*) (A7) Saya merasa sulit mencatat materi matematika dalam bentuk gambar atau grafik (*I prefer to read mathematics books I find it difficult to record mathematical material in the form of pictures or graphs aloud*.) (A8) Saya senang ketika menyajikan jawaban dari soal matematika dalam bentuk tulisan (*I enjoy presenting answers to maths problems in written form*)
Kinesthetic	(K1) Ketika istirahat saya lebih suka bermain dengan teman daripada duduk diam di dalam kelas (*During breaks, I prefer to play with friends rather than sit quietly in class*) (K2) Saya tidak betah berdiam diri saat istirahat *(I don't feel comfortable standing still during breaks*) (K3) Ketika membaca buku matematika, saya menggunakan jari untuk menunjuk kata-kata pada buku (*When reading a maths book, I use my finger to point to the words in the book*).

(K4) Saya merasa kesulitan ketika membaca buku matematika tanpa menggunakan *pena untuk menunjuk tulisan pada buku (I find it difficult to read maths books without using a pen to point at the writing in the book*)
(K5) Saya suka mata pelajaran matematika yang memiliki kegaitan praktikum (*I like maths subjects that have practical activities.*
(K6) Saya merasa tertarik ketika guru matematika memberi tugas berupa proyek atau membuat produk (*I feel interested when my maths teacher assigns a project or makes a product*).
(K7) Menggerakkan anggota tubuh ketika menghafal, membantu saya dalam mengingat (*Moving my limbs when memorising helps me to remember*)
(K8) Praktik sangat membantu saya dalam memahami materi Pelajaran matematika (*Practice really helps me understand the material Maths lessons*)

Providing and Considering the Study of Experts on the Initial Item Pool

The LSC-ME items that have been developed are then tested for content validity. The aim is to seek feedback from experts in relevant fields. They will provide input related to the relevance of each item to the construct being measured as well as the quality of the language or terms used.

Content validity involved four experts in the field of mathematics education with doctoral degrees, two of whom were professor and associate professor. The results of the expert's assessment were then analysed using the Aiken index. The validity of an item is said to be less if the index is less or equal to 0.4, moderate validity if the index is between 0.4 to 0.8, while high validity if the index is greater than 0.8 (Haryudo et al., 2019). Details of the content validation results are shown in Table 2

Table 2. Results of content validity analysis using the Aiken Index formula V

No.	Assessment Aspect	R1	R2	R3	R4	V	Category
	Content Aspect						
1.	Statements number 1 to 8 are in line with the objective to identify visual learning styles and are clearly stated	5	4	5	5	0,94	High
2.	Statements number 9 to 16 correspond to the objective to identify auditory learning styles and are clearly stated	5	4	5	5	0,94	High
3.	Statements number 17 to 24 correspond to the objective to identify kinesthetic learning styles and are clearly stated	5	4	5	5	0,94	High
	Aspect Instructions						
4.	The questionnaire instructions are clearly stated	5	5	5	4	0,94	High
5.	The questionnaire instructions are not ambiguous.	5	5	5	5	1,00	High
	Language						
6.	Questionnaires use language that is appropriate to the developmental level (easy to understand) of learners	5	4	4	5	0,88	High
7.	Questionnaires use language that is communicative and does not cause double meanings	5	4	5	5	0,94	High
8	Questionnaires use sentences that are easy for students to understand	5	4	4	5	0,88	High

R1, R2, R3, R4 : First to fourth validator

Based on Table 2, that all LSS-ME instrument items have a V value of more than 0.8. This value indicates that the item is said to be valid with a high category (Retnawati, 2016). This also means that experts agree that the instrument items have conformity to the concept or factor being measured.

Refining and Validating the Scale

After the instrument is declared valid in the context of content, at this stage the instrument is tested empirically. The aim is to ensure that the items of the instrument are able to measure the aspects of learning style accurately and consistently. This process is called construct validity. The tested aspects of factor analysis include the KMO value and Bartlett's test, determining the AIC value, and the LF value. The detailed results are presented in Table 3 and Table 4.

Table 3. KMO and Bartlett's Test

Factor	Kaiser-Meyer-Olkin (KMO)	Bartlett's Test of Sphericity (Sig value)
Visual	0,614	0,000
Auditory	0,610	0,000
Kinesthetic	0,652	0,000

Table 3. Anti-image Correlation and Loading Factor

Factor and Item	Anti-Image Correlation (AIC > 0,05)	Loading Factor (LF > 0,04)	Decision
Visual			
V1	0,602	0,674	Valid
V2	0,601	0,659	Valid
V3	0,565	0,530	Valid
V4	0,691	0,693	Valid
V5	0,658	0,493	Valid
V6	0,612	0,288	Invalid
V7	0,533	0,274	Invalid
V8	0,609	0,493	Valid
Auditory			
A1	0,467	0,291	Invalid
A2	0,731	0,513	Valid
A3	0,706	0,660	Valid
A4	0,660	0,599	Valid
A5	0,549	0,678	Valid
A6	0,580	0,779	Valid
A7	0,483	0,237	Invalid
A8	0,686	0,395	Invalid
Kinesthetic			
K1	0,525	0,475	Valid
K2	0,577	0,559	Valid
K3	0,637	0,428	Valid
K4	0,551	0,131	Invalid
K5	0,706	0,754	Valid
K6	0,757	0,736	Valid
K7	0,649	0,540	Valid
K8	0,722	0,755	Valid

KMO is an initial test related to the adequacy of the sample used. It is a prerequisite whether factor analysis can be continued or not (Williams, 2010). Based on Table 3, the KMO value of each factor is greater than 0.5 (Visual = 0.614, Auditory = 0.610, kinesthetic = 0.652). this means that the factor analysis test is eligible for use. Based on the sig value of Bartlett's test, the value of the three learning style factors is 0.000 or less than 0.5. This indicates that the factors have a high correlation to the sample (Alias, 2015).

Furthermore, Table 4 shows the AIC and LF values. The anti-image correlation value aims to ensure that items can be predicted and analysed further, if the value is more than 0.5. While the last step of the construct validity test is to determine the loading factor value. The goal is to see the correlation between the factor and its supporting variables (Hajjar, 2018). It can also be interpreted that the supporting variable contributes significantly to the underlying factor, if the value is more than 0.4.

Based on the AIC and LF values shown in Table 4, there are 2 items on the visual learning style factor, 3 items on the auditory learning style factor, and 1 item on the kinesthetic learning style factor that do not meet the criteria for values greater than 0.5 and more than 0.4 on AIC and LF. So that items V6, V7, A1, A7, A8 and K4 are declared invalid. This means that these items do not contribute significantly to the factor. Invalid items must be eliminated and cannot be used for further tests. Items of instruments that have been declared valid in the previous test, continued with the reliability test using Cronbach's Alpha Test. The test results are presented in Table 5

Table 5. Cronbach's Alpha Test

Factor and Item	Cronbach's Alpha (for each factor)	Cronbach's Alpha (for All item)
Visual		
V1		
V2		
V3	0,639	
V4		
V5		
V8		
Auditory		
A2		
A3	0,687	
A4		0,801
A5		
A6		
Kinesthetic		
K1		
K2		
K3		
K5	0,718	
K6		
K7		
K8		

Table 5 shows that the LSS-ME instrument through Cronbach's alpha test technique is a reliable instrument. The alpha value of each factor and overall is more than 0.6. The alpha value for each factor (Visual = 0.639, Auditory = 0.687, kinesthetic = 0.718), while for the whole is 0.801. With this value, it means that the LSS-ME instrument is categorized as reliable.

Finalizing the Scale

The last steps of the scale development is to finalize the scale after content validity, construct validity, and reliability tests. Only instrument items that are declared valid and reliable as the constituent of each learning style factor. The visual learning style aspect has 6 statement items, auditory has 5 statement items, while kinesthetic has 7 statement items. The following is presented in Table 6, the final LSS-ME instrument that has fulfilled the aspects of content and construct validity and reliability.

Table 6. Final of LSS-ME

Factor	Statement (Indonesian- English Version)
Visual	Saat belajar matematika di kelas, saya lebih mudah mengingat dengan cara melihat gambar, diagram, maupun grafik (*When learning maths in class, I find it easier to remember by looking at pictures, diagrams and graphs*)
	Saya merasa sulit ketika memahami materi matematika, jika penyajiannya menggunakan gambar, diagram maupun grafik (*I find it difficult to understand maths material if it is presented using pictures, diagrams or graphs*.)
	Saya lebih suka mencatat materi matematika dalam bentuk gambar, grafik agar mudah dipahami dan diingat (*I prefer to record mathematics material in the form of pictures, graphs so that it is easy to understand and remember*)
	Saya sulit menyajikan jawaban dari soal matematika ke dalam bentuk gambar dan grafik (*I find it difficult to present answers to maths problems in the form of pictures and graphs*.)
	Saya sulit memahami materi matematika yang hanya disajikan dalam bentuk tulisan (*I find it difficult to understand mathematics material that is only presented in written form*)
Auditory	Saya cendrung sulit untuk memberikan penjelasan yang detail ketika diberi pertanyaan matematika oleh guru (*I tend to find it difficult to give detailed explanations when asked maths questions by my teacher*).
	Saya mudah dalam memahami materi matematika melaui video pembelajaran (*I find it easy to understand maths material through learning videos*)
	Ketika berdiskusi Pelajaran matematika di kelas, saya selalu berbicara dengan lancar dan tidak gugup (*When discussing maths lessons in class, I always speak fluently and am not nervous*)
	Saya merasa kesulitan untuk berbicara atau menyampaikan materi matematika ketika sedang presentasi didepan kelas (*I find it difficult to speak or convey mathematics material when presenting in front of the class.*)
	Saya lebih mudah memahami materi matematika ketika saya membaca dengan bersuara (*I find it easier to understand maths material when I read aloud*)
	Saya lebih suka membaca buku matematika dengan suara yang keras (*I prefer to read maths books out loud*)
Kinesthetic	Ketika istirahat saya lebih suka bermain dengan teman daripada duduk diam di dalam kelas (*During breaks, I prefer to play with friends rather than sit quietly in class*)
	Saya tidak betah berdiam diri saat istirahat *(I don't feel comfortable standing still during breaks*)
	Ketika membaca buku matematika, saya menggunakan jari untuk menunjuk kata-kata pada buku (*When reading a maths book, I use my finger to point to the words in the book*).
	Saya suka mata pelajaran matematika yang memiliki kegaitan praktikum (*I like maths subjects that have practical activities.*
	Saya merasa tertarik ketika guru matematika memberi tugas berupa proyek atau membuat produk (*I feel interested when my maths teacher assigns a project or makes a product*).
	Menggerakkan anggota tubuh ketika menghafal, membantu saya dalam mengingat (*Moving my limbs when memorising helps me to remember*)
	Praktik sangat membantu saya dalam memahami materi Pelajaran matematika (*Practice really helps me understand the material Maths lessons*)

The LSS-ME instrument, which empirically fulfils the aspects of validity and reliability. valid and reliable, can be used as an assessment to determine the learning style tendencies of students in learning mathematics at the junior high school level. The development of the instrument was carried out through the integration and synthesis of theoretical findings from DePorter & Hernacki (1992), Fleming & Baume (2006), Othman & Amiruddin (2010), and Wiedarti (2018) related to learning styles. Content validation using the Aiken index formula indicated that experts agreed that the developed items measured the scale factors of Visual, Auditory, and Kinesthetic. The results of the factor analysis showed that 18 items met the validity criteria, while the other 6 items were invalid.. Additionally, the overall reliability coefficient reached 0.801, indicating good internal consistency. These findings align with previous studies, such as those conducted by Ardyani et al., (2020), Nizaruddin et al., (2020), and Astuti et al., (2023) which also concluded that the VAK learning style scale is a valid and reliable non-cognitive instrument applicable in various educational contexts.

However, this study also reveals several important differences. First, the conceptual approach in this study is more comprehensive because it combines four learning style theory models, whereas previous studies generally refer to only one theoretical source (e.g. Chislett & Chapman, 2005). According to Clark and Watson (2019), the development of theory-based instruments provides higher construct validity because it combines a broad conceptual framework. This is reinforced by the use of factor analysis in this study, which allows for empirical assessment of dimensional structure, whereas previous studies only used Pearson correlations.

In general, the results of this study indicate that the learning style instrument developed has met the criteria for validity and reliability, making it suitable for use as a non-cognitive measurement tool to identify students learning style preferences. This instrument has practical implications that enable educators to design teaching methods and media that are more suited to students' characteristics or differentiated learning strategies based on learning styles.

However, this study has several limitations, including the use of convenience sampling as the sampling technique, meaning that the sample only comes from one level of education, namely private secondary schools. This limits the generalisation of the findings to a broader context. Based on limitations, it is recommended that future research employ sampling techniques involving a more diverse population, both in terms of educational level and school type. Additionally, the development of the instrument should be further explored through more complex analyses, such as structural equation modelling (SEM) or the Rasch model.

CONCLUSION

The LSS-ME instrument that has been developed has met the criteria of valid and reliable based on the data obtained. The factors of this scale are the types of learning styles namely visual, auditory and kinesthetic. The validity test results showed that of the eight statements in each learning style category, there were six valid and two invalid statements in the visual learning style, five valid and three invalid statements in the auditory learning style, and seven valid and one invalid statement in the kinesthetic learning style. The invalid statements were then eliminated from the instrument. The reliability test on all valid items yielded a Cronbach's Alpha value of 0.801, indicating a high level of internal consistency. The reliability values for each factor were 0.639 for visual learning style, 0.687 for auditory learning style, and 0.718 for kinesthetic learning style. Thus, this instrument is suitable for use as a non-cognitive measurement tool to identify students' learning style tendencies, particularly in mathematics learning.

This scale can be used as a non-cognitive assessment tool to map students learning style tendencies before the learning design stage is implemented. The data generated through this measurement provides an objective foundation for educators to formulate choices of teaching methods and media that align with students' individual characteristics. This study still has some limitations, including the number of samples used and other analytical techniques. Therefore, further research can use a larger sample and other analytical models, such as the Rasch Model or structural equation modelling (SEM).

AUTHOR CONTRIBUTIONS STATEMENT

RR : Conceptualization, writing - original draft, supervised the project
RA : Writing to the final version of the manuscript, data analysis
EN : Writing - original draft, data collection

MA : Data retrieval, provided critical feedback the research, analysis and manuscript
AS : Project administration, data collection

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