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Validity and reliability: teachers' pedagogical instrument for identifying sensory-motor abilities in handwriting readiness

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ABSTRACT

The teacher's ability to identify students' sensory motor skills is very important. Sensory motor skills are the foundation for children's handwriting skills. However, there is no instrument to measure teachers' abilities in this regard. This study aims to test the validity and reliability of the instrument measuring teachers' pedagogical knowledge in identifying students' sensory-motor abilities. The data was collected using a questionnaire. A total of 552 teachers responded to the survey. The data were analyzed using exploratory factor analysis (EFA). The study results have developed a questionnaire with four construct components with 39 items. All four constructs have a high-reliability index. The EFA analysis indicated that all items were accepted with high agreement. The results prove that the instrument is highly valid and reliable. Based on the test results, this instrument is recommended for measuring pedagogical knowledge teachers in identifying sensory-motor abilities for elementary school students' handwriting readiness. The measurement results can be used to determine appropriate training for teachers in developing the sensory-motor abilities of elementary school students. The innovation of this research is the development and validation of an instrument that can measure teachers' pedagogical knowledge in identifying the sensorimotor abilities of elementary school students.

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1. INTRODUCTION

Teachers play a crucial role in supporting students to develop their sensorimotor skills to their fullest potential. Teachers must identify students' sensorimotor skills to ensure that they can quickly develop the appropriate competencies. However, not all teachers possess the necessary knowledge to identify and train students' sensorimotor skills to enhance their handwriting abilities. The ability to write legibly is a fundamental skill essential for academic success and a predictor of future success in adulthood [1]. Developing handwriting skills is associated with the growth of reading and oral language abilities. The development of handwriting skills provides students with the capacity to learn across a variety of disciplines [2]. The development of handwriting skills can positively influence a number of critical areas, including

literacy, creativity, productivity, and student achievement [3]–[6]. Barriers to handwriting ability can significantly impact students' academic and emotional development [7], [8]. From an academic perspective, students who have difficulty with handwriting may be unable to express their ideas effectively, which could result in lower academic grades. From an emotional standpoint, handwriting difficulties can lead to reduced self-confidence and feelings of frustration or anxiety. Therefore, it is crucial to provide appropriate support to students who face difficulties in handwriting.

The ability to write is a fundamental aspect of early academic development, and educators must pay special attention to this area. One of the principal factors that facilitate handwriting ability is sensorimotor development [9]–[12]. The sensory processing system comprises four components: the sensory system, sensory-motor development, perceptual-motor, and cognition-intellect [13], [14]. Sensory processing, also known as the pyramids of learning, impacts students' learning readiness, including their readiness to learn how to write. Several factors of physical maturity influence children's handwriting ability. These include kinesthesia, motor planning, eye-hand coordination, visual-motor integration, and hand manipulation skills [15], [16]. Kinesthesia can be defined as the awareness of the perception of object weight, direction of joints and limb movements [17]. In writing, the ability to form letters in a sequence necessitates the continuous utilization of motor planning skills, which impacts the child's capacity to plan, sequence, and form letters coherently when engaged in writing. When writing on lined paper, coordinating hand and eye movements is essential for children [18]. The outcome of handwriting is largely contingent upon the input and continuity of visual system instructions. To illustrate, writing letters of a particular shape requires a continuous visual system. For instances where the kinesthetic function is impaired, the visual system's role during writing becomes more dominant. The process of copying letters from printed text to their corresponding Latin counterparts requires the involvement of visual-motor intelligence [19]. During this activity, children must simultaneously focus on the shape and characteristics of the letters while manipulating the writing utensil. Thus, when the child moves the hand while writing, the visual system provides information about the layout of the space available for writing.

Handwriting necessitates a multifaceted approach, encompassing perceptual, motor, and cognitive complexities [20]. Handwriting is a complex activity that necessitates the integration of multiple movements, including those of the arm, hand, fingers, and eyes [21]. Handwriting is a complex neurophysiological activity, the successful completion of which requires several skills, including motor skills. Several factors influence a child's ability to handwrite. These include motor skills, behavior, perception, memory, the ability to cross-modal, using the dominant hand, and understanding instructions [22]. Children still developing their motor skills may experience difficulties when attempting to write [23]. Their writing may appear unclear or disjointed, or they may need help following the page's lines. Additionally, writing a single word or sentence may be significantly longer than typically observed in other children.

Most students are expected to have developed the requisite sensory-motor skills by the age of seven. Consequently, by the time they commence their first year of primary school, they will be adequately prepared to learn to write. At the commencement of their academic careers, these abilities have yet to become automatic. It indicates that students in the primary grade struggle to draw letters and spell words correctly. As a result, it is critical to promote transcribing training so that it becomes more expected from a young age. Automating these skills is crucial as it frees up attentional resources that can be allocated to more complex cognitive processes, such as students' executive functioning [24], [25]. Nevertheless, the evidence indicates that many elementary school students still exhibit immaturity in their sensory-motor skills, which adversely affects their writing abilities. To ensure readiness for handwriting, a proper pedagogical understanding is required to identify students' sensorimotor abilities.

Teachers must be able to identify students' sensory-motor abilities to optimize the specific sensory-motor areas that need development. However, it should be noted that not all teachers possess the requisite knowledge to identify and train students' sensory motor skills to support students' handwriting abilities. Interviews with teachers revealed that they are unaware of the significant role sensory-motor skills play in students' handwriting abilities. When students struggle with handwriting, teachers tend to directly teach letters and words without first assessing sensory-motor skills.

Given this background, teachers require information and even training on how to identify students' sensory-motor skills. However, before such training can be developed, an instrument is needed to measure teachers' pedagogical knowledge in identifying sensory-motor skills. Importantly, the evaluation of this knowledge requires a valid and reliable instrument to ensure that the results can effectively inform the design of appropriate teacher training programs. An instrument to measure teachers' pedagogical knowledge in identifying students' sensory-motor abilities has not been developed previously. Prior research has focused solely on testing the validity and reliability of instruments measuring teachers' general pedagogical knowledge, such as assessments of teacher quality [26]. The novelty of this research is the development and validation of an instrument that can measure teachers' pedagogical knowledge in identifying the sensorimotor abilities of elementary school students. In this context, testing the validity and reliability of the

instrument is critical to ensure it provides consistent and accurate results aligned with the measurement objectives. This study aims to test the validity and reliability of an instrument designed to assess teachers' pedagogical knowledge in identifying students' sensory-motor skills.

2. METHOD

A validation and reliability test were conducted on an instrument to assess teacher competency in identifying sensory-motor abilities for elementary school students' handwriting readiness. The population of this study is elementary school teachers in Yogyakarta, Indonesia. The sampling technique employed random sampling and stratified area sampling. The areas included were Yogyakarta City, Bantul Regency, Sleman Regency, Gunungkidul Regency, and Kulonprogo Regency. This study employed a survey is 18,630, so based on the Krejcie and Morgan [27] table, the minimum number of samples is 376. The data collection instrument was a questionnaire distributed via Google Forms. A total of 552 teachers completed the instrument. The number of respondents was deemed to satisfy the sampling criteria set forth by Krejcie and Morgan [27] theory.

The teacher pedagogical competence questionnaire was developed based on the Indonesian teacher competence standards [28] and the pedagogy content knowledge framework [29]. The scale used in the questionnaire employed a five-point interval scale. The instrument's validity was evaluated using face validity and content validity. The instrument was then assessed by five highly qualified experts in the field, after which improvements were made based on their input. Subsequently, the instrument was tested on teachers, and the data from the pilot test were analyzed using exploratory factor analysis (EFA).

3. RESULTS AND DISCUSSION

The initial questionnaire comprised 60 items grouped into four aspects: pedagogical knowledge of sensory systems, pedagogical knowledge of sensor-motor, pedagogical knowledge of perceptual-motor, and pedagogical understanding of pre-writing skills. Based on the expert evaluation results, four items were identified as requiring replacement. These were replaced with new questions, resulting in 60 items distributed across four aspects, with 15 items per aspect.

After completing the item-generation stage and evaluating the 60-item questionnaire by experts, the questionnaire was tested on respondents. Subsequently, the trial data underwent an EFA [30]. By the recommendations, items below 0.60 should be excluded from the questionnaire.

The Kaiser-Meyer-Olkin (KMO) index is a statistical value used to determine whether the sample is sufficient for factor analysis. The KMO index is a statistical value employed as an indicator to ascertain the sufficiency of the sample for factor analysis. The second measure of sample suitability is Bartlett's test of Sphericity, which evaluates the overall significance of the intercorrelations between items on the measurement instrument. The KMO index measures sample suitability and a 0.50 or above is deemed an appropriate threshold [30]. Bartlett's test of sphericity is deemed significant if the p-value is less than 0.005 [31]. These two statistical values establish the minimum standards that must be met before conducting factor analysis. The results of the KMO values, Bartlett's test of sphericity, eigenvalues, and variance values of each factor are presented in Tables 1-3.

The EFA results presented in Table 1 indicate that the KMO values for all constructions exceed 0.6, with the following values: pedagogical knowledge of the sensory system =0.750, pedagogical knowledge of sensor-motor =0.756, pedagogical knowledge of perceptual motor =0.761, and pedagogical knowledge of pre-writing skills =0.762. These values suggest that the sampling adequacy is satisfactory for factor analysis. Additionally, the significance values from Bartlett's test of Sphericity for all components are less than 0.005, indicating that the variables are sufficiently independent and the data structure is appropriate for proceeding with factor analysis [32]. This confirms that the constructions are well-suited for dimensional reduction and further examination of the factor structure.

Table 1. KMO and Bartlett's test

KMO measure of sampling adequacy		Pedagogical knowledge of sensory system 0.750	Pedagogical knowledge of sensor-motor 0.756	Pedagogical knowledge of perceptual motor 0.761	Pedagogical knowledge of pre-writing skills 0.762
Bartlett's test of sphericity	Approx. Chi-square	3357.645	4387.545	5793.573	6157.557
	df	105	105	105	105
	Sig.	0.000	0.000	0.000	0.000

The value of total variance explained, representing the percentage of items utilized to assess the research variables, is a key indicator of the validity of our research. The analysis of the construct of teacher pedagogical knowledge demonstrates that the items with a weighted value of the variance contribution for each factor can be observed in Table 2. The variance explained for this teacher competency construct is a significant 56.426%, surpassing the minimum requirement of 50% outlined in the literature [33]. The variance value of 15.253%, though less than 50%, does not indicate a standard method [34] and thus, four main factors were extracted in the teacher pedagogical knowledge construct.

A component matrix with varimax rotation was performed to show the correlation between items and their factors. All items of the four teacher pedagogical knowledge constructs were analyzed. Table 3 shows the weighted values from the rotated factor analysis for the pedagogical knowledge constructs. The rotated component matrix results show that out of 60 items, only 39 items qualify for the teacher competency construct. A total of 21 items had to be removed because they did not qualify (factor weight values less than 0.60).

Table 2. Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)
1	9.052	15.253	15.253	9.052	15.253	15.253
2	8.904	14.677	29.930	8.904	14.677	29.930
3	8.730	14.517	44.447	8.730	14.517	44.447
4	7.207	11.979	56.426	7.207	11.979	56.426

Extraction method: principal component analysis

Table 3. Rotated component matrix (for each construct)

Item	Component	FL component			
		1	2	3	4
PK1	Pedagogical knowledge of sensory system	0.749			
PK2		0.734			
PK3		0.603			
PK4		0.749			
PK5		0.628			
PK6		0.752			
PK7		0.723			
PK8		0.670			
PK9		0.634			
PK10			0.786		
PK11	Pedagogical knowledge of sensor-motor		0.623		
PK12			0.603		
PK13			0.696		
PK14			0.653		
PK15			0.623		
PK16			0.729		
PK17			0.736		
PK18			0.608		
PK19			0.835		
PK20			0.837		
PK21			0.768		
PK22	Pedagogical knowledge of perceptual motor			0.816	
PK23				0.612	
PK24				0.639	
PK25				0.850	
PK26				0.650	
PK27				0.861	
PK28				0.783	
PK29				0.669	
PK30				0.634	
PK31	Pedagogical knowledge of pre-writing skills				0.686
PK32					0.836
PK33					0.804
PK34					0.874
PK35					0.780
PK36					0.677
PK37					0.826
PK38					0.684
PK39					0.722

Following the teacher pedagogical knowledge construct presented in Table 3, the rotated factor weight analysis of the teacher competency construct was represented by several pedagogical knowledge areas. They were sensory system, sensor-motor, perceptual motor, and pre-writing skills. The interpretation of the data indicates that each sub-construct of teachers' pedagogical knowledge contributes positively to the developed instrument, as evidenced by factor values exceeding the commonly accepted threshold (≥0.60).

The factor analysis for the pedagogical knowledge of the sensory system sub-construct demonstrated that the nine accepted items exhibited scores between 0.603 and 0.749. This indicates that the items within this sub-construction are sufficiently robust in representing the sensory system dimension of teachers' pedagogical knowledge. The factor analysis for the pedagogical knowledge of sensor-motor sub-construction demonstrated that the 12 accepted items exhibited factor values between 0.603 and 0.837. This sub-construct has a broader range of factor values, indicating that the items effectively capture a good variation in representing the sensory-motor aspect. The factor analysis for the pedagogical knowledge of the perceptual-motor sub-construct demonstrated that the nine accepted items exhibited factor values between 0.612 and 0.861. The relatively high factor values indicate that the motor perception dimension is strongly represented in the measurement. The factor analysis for the pedagogical knowledge of pre-writing skills sub-construction demonstrated that the nine accepted items exhibited factor values between 0.677 and 0.874. This sub-construction has the highest value compared to the other sub-constructions, indicating that the aspect of pre-writing skills demonstrates very strong consistency within the instrument. Overall, the factor analysis results show that all four sub-constructs exhibit good reliability in representing the dimensions of teachers' pedagogical knowledge related to students' sensory-motor abilities for handwriting readiness. This supports the validity of the instrument used in the study.

Furthermore, the data was tested for reliability. The term 'reliability' describes the measurement instrument's stability and consistency over time [35]. In other words, reliability denotes the capacity of a measurement instrument to yield analogous results when evaluated at disparate points in time. The internal consistency approach was employed as the methodology for the reliability test. The internal consistency approach to measurement relies on the correlation of each item that constitutes the measurement instrument. The measurement instrument is employed to ascertain the consistency of the items it comprises and evaluate the extent to which it can accurately measure a specific behavioral or qualitative trait [36]. The reliability test was conducted using the IBM SPSS statistics software, version 26. Cronbach's alpha (α) coefficient index test was employed to ascertain the reliability of the research instrument. The alpha index value range is between 0.00 and 1.00. An alpha value exceeding 0.5 is indicative of an acceptable level of reliability. A lower alpha value reduces the instrument's reliability [37], [38]. The results of the reliability test are presented in Table 4.

Table 4. Cronbach's alpha reliability index for teacher pedagogical knowledge construct

Component	Number of items	Cronbach's alpha value
Pedagogical knowledge of sensory system	9	0.876
Pedagogical knowledge of sensor-motor	12	0.837
Pedagogical knowledge of perceptual motor	9	0.852
Pedagogical knowledge of pre-writing skills	9	0.915
Total	39	0.807

Table 4 presents Cronbach's alpha coefficient index values for the construct of teacher pedagogical knowledge. The data interpretation indicates that the teacher pedagogical knowledge instrument demonstrates a high level of reliability, as evidenced by the Cronbach's alpha values for each sub-construct and the overall items. The Cronbach's alpha for the pedagogical knowledge of the sensory system component is 0.876, indicating high reliability. The items within this sub-construction consistently measure the sensory system dimension of teachers' pedagogical knowledge. The Cronbach's alpha for the pedagogical knowledge of sensor-motor component is 0.837, also reflecting high reliability. This sub-construct consistently represents the sensory-motor dimension. Cronbach's alpha for the pedagogical knowledge of perceptual motor component is 0.852, confirming consistency and reliability in measuring the motor perception dimension. The Cronbach's alpha for the pedagogical knowledge of pre-writing skills component is 0.915, the highest among the sub-constructs. This indicates very high reliability, suggesting that the items within this dimension are highly consistent. Overall, the Cronbach's alpha for all items is 0.807, signifying that the items within the teacher competency construct exhibit high reliability and consistency. Collectively, these values provide strong evidence that the instrument used has good reliability and is dependable for evaluating teachers' pedagogical knowledge across various dimensions, including the sensory system, sensor-motor, motor perception, and pre-writing skills.

Sensory motor skills play a pivotal role in the development of children's handwriting skills [39]–[41]. The ability to effectively coordinate the eyes and hands, control fine muscles, and accurately perceive space is crucial for forming letters correctly and neatly [42]–[44]. Moreover, sensory motor skills aid in children's understanding of fundamental spatial concepts in handwriting, such as the distance between letters and lines [45]–[47]. Recognizing the importance of sensory-motor skills in students' development and identifying the aspects that need attention is a key responsibility for teachers. However, not all teachers have the expertise to assess and train students' sensory-motor abilities accurately, particularly concerning handwriting [48]–[50]. This underscores the need for an instrument that can effectively measure pedagogical knowledge in identifying sensory-motor abilities for elementary school students' handwriting readiness.

The tests presented in Tables 1-4 demonstrate that the instrument developed is valid and exhibits high and consistent reliability, thereby establishing its suitability for use. This instrument can then ascertain the extent of pedagogical knowledge in identifying sensory-motor abilities. The identification results will be used to organize teacher training in developing students' sensory-motor abilities.

4. CONCLUSION

The research has developed 39 items that can be used to measure pedagogical knowledge in identifying sensory-motor abilities for elementary school students' handwriting readiness. The developed instrument is designed to comprehensively assess teachers' pedagogical knowledge. The reliability of this instrument is based on the results of carefully conducted validity and reliability tests. The EFA indicate that the four components of pedagogical knowledge in identifying sensory-motor abilities meet the criteria for reliability and are well-suited for use as a measurement tool. The instrument also demonstrates strong content validity and construct validity, as confirmed through validity testing. The KMO values further reinforce the findings that each item aligns well with its respective dimensions, ensuring optimal appropriateness and representation of the measured constructs. Additionally, the high Cronbach's alpha values indicate that the instrument has a consistent and robust level of reliability in assessing teachers' abilities. Based on the results of validity and reliability tests, this instrument is recommended for use in measuring teachers' pedagogical knowledge in identifying elementary school students' sensory-motor abilities. The information derived from this measurement can serve as a solid foundation for designing appropriate training programs for teachers, aimed at supporting the optimal development of students' sensory-motor skills and enhancing their readiness for handwriting.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest regarding the publication of this paper. Any affiliations, financial interests, or personal relationships that could influence or bias the work have been disclosed and are duly noted. The research was conducted independently and the findings represent the authors' genuine analysis and perspectives.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author [HHS] on request.

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