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# A Multidimensional Model of Pre-Writing Competence in Special Education Students: Validation Using Confirmatory Factor Analysis (CFA) Approach

**Dwiyatmi Sulasminah<sup>\*</sup>, Tatiana Meidina**

Department of Special Education, Universitas Negeri Makassar, Makassar, Indonesia

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**\*Corresponding Author:** D. Sulasminah  
✉ [dwiyatmi.sulasminah@unm.ac.id](mailto:dwiyatmi.sulasminah@unm.ac.id)



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## Abstract

Children with cerebral palsy (CP) face distinct challenges in pre-writing acquisition, yet existing assessment tools often prioritize motor deficits while overlooking environmental barriers. This study aimed to validate a multidimensional measurement model of pre-writing challenges and supports for students with CP in Indonesian special schools. Grounded in the ICF-CY, HAAT, and Universal Design for Learning (UDL) frameworks, the model comprised four latent constructs: motor impairment to writing (MIW), pre-writing activity difficulties (PAD), inclusive learning environment (ILE), and adaptive pre-writing media (APM). A total of 108 students with CP in the pre-writing stage were rated by their teachers using a 5-point Likert questionnaire. Confirmatory Factor Analysis (CFA) was conducted with IBM SPSS AMOS to examine model fit, factor loadings, and reliability. After removing poorly performing indicators, the final model with four factors and 19 indicators demonstrated excellent fit (Chi Square= 1.01,  $p = 0.43$ , CFI = 0.998, TLI = 0.997, RMSEA = 0.007, PNFI = 0.79). All standardized factor loadings ranged from 0.59 to 0.94 ( $p < 0.001$ ), and Cronbach's alpha values for the four constructs were between 0.87 and 0.89, indicating high internal consistency. Moderate to strong inter-factor correlations were found, particularly between PAD and ILE, highlighting the close interplay among functional limitations, activity demands, and classroom conditions. The validated instrument offers a concise framework for identifying pre-writing challenges and environmental supports in students with CP. It can inform individualized intervention planning, the design of inclusive learning environments, and the development of adaptive pre-writing media in resource-constrained settings.

**Keywords:** Assessment Validation; Adaptive Pre-Writing Media; Cerebral Palsy; Inclusive Education; Pre-Writing Skills; Motor Impairments.

## 1. INTRODUCTION

Children with special educational needs (SEN) continue to encounter substantial barriers in achieving equitable and meaningful participation in education. Global analyses indicate that children with disabilities are significantly less likely than their peers to attain foundational academic competencies and are disproportionately excluded from learning activities requiring motor precision, postural stability, and coordinated manual control [1], [2]. Early literacy activities, particularly pre-writing and handwriting tasks, present heightened challenges for learners with motor

impairments, thereby limiting their academic engagement and reducing opportunities to develop essential communication skills [3].

Within this population, children with cerebral palsy (CP) constitute one of the largest and most vulnerable groups. CP is the most prevalent motor disability in childhood. It is characterized by disturbances in movement, posture, and muscle tone that directly impede participation in school activities requiring fine motor precision [4], [5]. Recent epidemiological reviews estimate CP prevalence at approximately 2.1 to 3.1 per 1,000 live births, with higher rates reported in low- and middle-income countries due to

disparities in perinatal care and early rehabilitation access [6], [7]. A growing body of evidence demonstrates that children with CP commonly exhibit difficulties in tool grasp, motor planning, finger dexterity, upper-limb control, and hand–eye coordination—skills that are fundamental for the acquisition of pre-writing and handwriting proficiency [8], [9]. Limitations in trunk stability and postural alignment further compromise their ability to maintain appropriate writing positions and execute consistent pre-writing strokes [10].

These functional challenges have significant implications for participation in school activities. Research employing the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) framework demonstrates that impairments in body functions often lead to activity limitations that, in turn, contribute to restrictions in participation in literacy-related tasks [11], [12]. Without targeted instructional supports and adequate environmental accommodations, children with CP are at heightened risk of falling behind in early literacy development, with potential long-term consequences for their educational trajectories.

In response to these concerns, education systems globally have emphasized the importance of inclusive practices that facilitate meaningful engagement for all learners, including those with motor impairments [13], [14]. Pre-writing and handwriting activities constitute essential components of early literacy development, and empirical research demonstrates that deficits in fine motor skills, visuomotor integration, and postural control substantially influence writing readiness and overall literacy outcomes [15], [16]. For children with CP, these challenges necessitate the provision of structured pedagogical supports, adaptive tools, and environmental modifications to mitigate motor demands during early writing experiences. Effective inclusive learning environments integrate assistive technologies, individualized educational plans, and collaborative practices among teachers, therapists, and families, all of which have been shown to enhance learners with motor impairments' access to writing tasks [17]–[19].

Despite these international advances, challenges remain evident in many developing contexts, including Indonesia. Although national policies endorse inclusive education, implementation at the school level is frequently constrained by limited resources, inadequate teacher preparation, the absence of adaptive tools, and minimal professional development focused on supporting students with motor impairments [20], [21]. Evidence from Southeast Asia similarly indicates that teachers often feel unprepared to address the motor, perceptual, and environmental needs of students with CP, reflecting a persistent gap between policy aspirations and classroom realities [22], [23]. Additionally, limited collaboration among classroom teachers, special educators, and therapists contributes to fragmented intervention practices, resulting in inconsistent support for children who require specialized assistance with pre-writing and writing tasks [24], [25]. These contextual challenges underscore the need for research examining the specific motor difficulties, pre-writing barriers, environmental conditions, and stakeholder perspectives that shape early writing experiences for children with CP in Indonesian inclusive schools.

Empirical investigations consistently highlight the influence of motor impairments on pre-writing and handwriting performance in children with CP. Deficits in graphomotor control, postural stability, finger dexterity, and visuomotor integration have been identified as key predictors of handwriting difficulties and reduced writing efficiency [3], [8]. Research on pre-writing skills further demonstrates that activities such as tracing, shape copying, and line drawing require adequate motor planning and hand–eye coordination, with difficulties often persisting without targeted intervention [26], [27]. Environmental influences including classroom layout, teacher attitudes, instructional adaptations, and access to assistive devices have also been recognized as critical determinants of school participation among children with CP [28], [29]. Nonetheless, studies that simultaneously address motor impairments, pre-writing difficulties, environmental barriers, and the perceived need for adaptive instructional media remain notably limited, particularly in low-resource educational settings.

Research frequently examines motor impairments or handwriting outcomes in isolation, rather than adopting an integrative framework such as the ICF-CY that considers interactions among body functions, activity demands, and contextual factors [12]. Furthermore, much of the current evidence is derived from clinical rather than authentic classroom contexts, leaving a limited understanding of the real-time challenges that children with CP encounter during school-based pre-writing tasks [30], [31]. Empirical studies exploring stakeholder perceptions of the need for adaptive pre-writing media particularly within conceptual frameworks such as the Human Activity Assistive Technology (HAAT) model or Universal Design for Learning (UDL) are also scarce [32], [33]. Finally, research from Southeast Asia and other low- and middle-income regions remains underrepresented, creating a substantial gap in the development of culturally and contextually appropriate interventions.

Despite mounting evidence on motor impairments and handwriting difficulties in children with CP, few studies have developed and validated integrated measurement models that simultaneously capture motor limitations, pre-writing activity demands, classroom inclusiveness, and the availability of adaptive media particularly in low- and middle-income settings. Existing research often focuses on either clinical motor outcomes or isolated handwriting performance, with limited attention to school-based environments and assistive supports. The present study addresses this gap by proposing and validating a four-factor measurement model grounded in the ICF-CY, HAAT, and UDL frameworks. Specifically, we aim to (a) examine the factorial validity and reliability of a teacher-rated instrument assessing motor impairments, pre-writing activity difficulties, inclusive learning demands, and adaptive pre-writing media in Indonesian special schools, and (b) explore the interrelationships among these constructs as a basis for designing targeted, context-appropriate interventions.

In line with the ICF-CY, motor impairment to writing (MIW) reflects body function limitations, whereas pre-writing activity difficulties (PAD) capture activity-level constraints in tasks such as tracing, copying, and connecting shapes. The inclusive

learning environment (ILE) represents environmental demands and barriers in classroom participation, including instructional pacing and task expectations, while adaptive pre-writing media (APM) corresponds to assistive technologies and supports as conceptualized in the HAAT model and UDL principles. Together, these four constructs operationalize a multidimensional view of pre-writing readiness that integrates impairments, activities, and contextual supports.

## 2. MATERIAL AND METHODS

### 2.1. Research Design

This study employed a quantitative cross-sectional survey design and utilized Confirmatory Factor Analysis (CFA) to test whether the observed items accurately represented four hypothesized latent factors. CFA, a theory-driven statistical approach, was selected to assess construct validity by confirming that each item aligned with its intended latent construct [34]–[36]. All analytical decisions, including factor structure and item grouping, were made a priori based on theoretical foundations to ensure both convergent and discriminant validity [37].

Data were collected through a field survey conducted in four public and private special schools in Makassar, Indonesia, to capture authentic information on students' pre-writing difficulties and learning environments. The inclusion of a field-based design enhanced ecological validity and allowed direct interaction with teachers and students for more accurate data interpretation [38]. Eligible participants included students aged 6–12 years with a confirmed diagnosis of cerebral palsy, who were in the pre-writing stage and could participate in classroom activities with or without assistive devices. Exclusions were made for students with severe visual or hearing impairments, uncontrolled epilepsy, or profound intellectual disabilities that prevented participation in pre-writing tasks.

### 2.2. Participants and Sampling

The target population comprised students with Cerebral Palsy (CP) enrolled in special education schools in Makassar. A total of 108 students participated, all of whom were in the pre-writing learning stage and exhibited motor impairments characteristic of CP, particularly fine-motor deficits known to affect handwriting readiness and early literacy development [3], [4]. Given that students with CP constitute a hard-to-reach population, the sample size of 108 represents a substantial and meaningful cohort within this context.

The sample size was adequate for Confirmatory Factor Analysis (CFA). Methodological guidelines recommend a minimum of 100–150 participants for stable factor solutions [39], [40], and simulation studies indicate that simple CFA models can be reliably estimated with samples of approximately  $N \approx 150$  [41]. Thus, the final sample provided sufficient statistical power and met the requirements for model convergence, even though strict adherence to the 10:1 indicator-to-sample ratio was not feasible.

Participants were recruited through purposive sampling in collaboration with several special schools in Makassar, enabling the inclusion of students actively engaged in pre-writing instruction and whose parents or caregivers provided informed consent. Data collection involved direct observation and assessment jointly conducted with classroom teachers to ensure ecological validity and accurate evaluation of motor-based pre-writing skills.

Ethical approval was obtained prior to data collection, and all procedures adhered to institutional and national standards for research involving vulnerable populations [42], including securing parental consent and child assent.

### 2.3. Instrument and Measures

Data were collected using a structured questionnaire developed specifically for this study, based on the literature in special education and expert consultation. The instrument was designed to measure four latent variables theoretically associated with pre-writing skill development among students with special needs. Each latent variable was operationalized through a set of observable indicators, as described below.

#### 2.3.1. Motor Impairment to Writing (MIW)

Motor Impairment to Writing assesses motor-related barriers excellent motor skills, postural stability, and movement control that may hinder a student's ability to complete writing or pre-writing tasks. This construct is measured with five indicators that capture difficulties in holding writing tools, controlling hand movements, maintaining a sitting posture, and sustaining motor endurance during graphomotor activities. Motor impairments directly influence graphomotor performance and writing readiness [3], [26].

**Table 1.** Research Instrument of Motor Impairment to Writing (MIW)

Constructs	Code	Indicators
Motor Impairment to Writing (MIW)	MIW1	The student has difficulty holding writing tools steadily while writing or drawing.
	MIW2	The student's hand movements are often uncontrolled, leading to lines or writing that appear shaky or inaccurate.
	MIW3	The student struggles to maintain an upright, stable sitting posture during pre-writing tasks.
	MIW4	The student shows rapid fatigue of the hand muscles when asked to write or trace shapes for a short period.
	MIW5	The student frequently misdirects hand movements compared to visual expectations (poor hand-eye coordination).

2.3.2. Pre-Writing Activity Difficulties (PAD)

Pre-Writing Activity Difficulties encompasses specific challenges that arise when students perform everyday pre-writing activities, such as tracing lines, drawing basic shapes, or following patterns. Six indicators (HAP1–HAP6) capture the degree of difficulty students experience with skills essential for early writing. Difficulties in pre-writing activities are often associated with deficits in visual–motor integration and visual perception [43].

**Table 2.** Research Instrument of Pre-Writing Activity Difficulties (PAD)

Constructs	Code	Indicators
Pre-Writing Activity Difficulties (PAD)	PAD1	The student has difficulty drawing straight or curved lines, as shown in the example.
	PAD2	The student struggles to trace simple shapes (circles, squares, slanted lines) without crossing the boundaries.
	PAD3	The student has difficulty connecting dots to form a continuous line or completing a shape.
	PAD4	The student struggles to copy basic letter-like forms (e.g., shapes resembling “I”, “O”, and “L”) from a model onto paper.
	PAD5	The student requires significantly more time than peers to complete pre-writing worksheets.
	PAD6	The student needs direct physical assistance (e.g., hand-over-hand support) to finish pre-writing tasks.

2.3.3. Inclusive Learning Environment (ILE)

An Inclusive Learning Environment refers to the environmental factors in inclusive classroom settings that may affect students’ pre-writing performance. Six indicators evaluate the extent to which the demands of the regular classroom such as following multi-step instructions, completing tasks within allotted time, keeping pace with peers, and requiring extra physical assistance pose challenges. Although some items share conceptual similarities with PAD, ILE emphasizes the situational demands of inclusion. Higher ILE scores indicate a greater need for environmental adaptation. Insufficiently adapted inclusive environments can intensify task demands for students with special needs [44], [45].

**Table 3.** Research Instrument of Inclusive Learning Environment (ILE)

Constructs	Code	Indicators
Inclusive Learning	ILE1	The classroom provides adjustable tables and chairs to help students

Constructs	Code	Indicators
Environment (ILE)		with CP maintain stable sitting posture during pre-writing tasks.
	ILE2	The school provides simple assistive tools (e.g., pencil grips, slant boards, arm supports) to assist CP students in pre-writing activities.
	ILE3	Teachers and peers show acceptance and support when CP students need additional time or different methods during pre-writing activities.
	ILE4	Parents are involved and support pre-writing exercises at home based on recommendations from teachers/therapists.
	ILE5	The school has policies supporting the use of adaptive media or technology for students with special needs.
	ILE6	Classroom teachers, special education teachers, and therapists regularly collaborate to design pre-writing activities for CP students.

2.3.4. Adaptive Pre-Writing Media (APM)

Adaptive Pre-Writing Media evaluates the availability and use of adaptive media and support tools that facilitate pre-writing skills. The construct comprises six positively phrased indicators, including the provision of adjustable classroom furniture, assistive tools (pencil grips, slant boards, wrist supports), supportive teacher–peer interactions, parental involvement in home-based pre-writing practice, school policies encouraging adaptive media or technology use, and regular collaboration among classroom teachers, special education teachers, and therapists. Access to adaptive interventions and assistive tools has been shown to enhance participation and motor performance in school activities [46], [47].

**Table 4.** Research Instrument of Adaptive Pre-Writing Media (APM)

Constructs	Code	Indicators
Adaptive Pre-Writing Media (APM)	APM1	The classroom provides adjustable tables and chairs to help students with maintain stable sitting posture during pre-writing tasks.
	APM2	The school provides simple assistive tools (e.g., pencil grips, slant boards, arm supports) to assist students in pre-writing activities.
	APM3	Teachers and peers show acceptance and support when students need additional time or different methods during pre-writing activities.
	APM4	Parents are involved and support pre-writing exercises at home, as recommended by teachers/therapists.

Constructs	Code	Indicators
	APM5	The school has policies supporting the use of adaptive media or technology for students with special needs.
	APM6	Classroom teachers, special education teachers, and therapists regularly collaborate to design pre-writing activities for students.

All questionnaire items were presented as declarative statements rated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). This response format is widely used in educational and psychological assessment because it permits reliable quantification of subjective observations. In this study, teachers or evaluators familiar with each student indicated the extent to which each statement reflected the student's typical abilities or needs. Lower scores signified that the described difficulty or support was not present, whereas higher scores indicated clear agreement that the behavior or support was characteristic of the student. The inclusion of a neutral midpoint allowed respondents to express uncertainty when a statement was neither clearly true nor false, thereby enhancing response accuracy.

The final instrument comprised 23 items across four constructs and underwent a systematic content validation process. Five experts in special education and occupational therapy independently rated each item for relevance, clarity, and representativeness using a 4-point scale. Item-level CVI values ranged from 0.80 to 1.00, and the overall scale-level CVI averaged 0.92, indicating strong content validity. A pilot test involving 10 teachers further confirmed item clarity, leading to minor wording adjustments prior to full implementation.

Despite the rigorous development process, several items intended to measure inclusive learning environment demands were inadvertently phrased in terms of students' observable task difficulties rather than explicit environmental features (pacing, task design, accessibility). This wording introduced partial conceptual overlap between the ILE and PAD constructs, potentially inflating inter-factor correlations and limiting the instrument's ability to distinctly capture environmental barriers. Future revisions should reframe these items to align more precisely with environmental dimensions and strengthen construct validity.

#### 2.4. Procedure and Data Collection

Data collection was conducted in the field over approximately four weeks. The research team coordinated with principals and teachers in participating special schools in Makassar to arrange on-site visits. During each visit, one or more researchers met directly with the teacher(s) or therapists responsible for the target students. In most cases, the homeroom or special education teacher completed the questionnaire for each student, as they were the most knowledgeable about the student's abilities. In several cases, researchers also conducted brief direct observations such as watching the student draw simple shapes or hold a pencil to

corroborate the teacher's judgments. Teachers then completed the Likert-scale questionnaire based on their ongoing classroom observations and the student's typical performance during the visit.

Each questionnaire required approximately 10–15 minutes to complete. Researchers remained available throughout the process to clarify any items (e.g., definitions of "basic letter-like forms" or "adaptive media") to ensure consistent interpretation. Teachers were instructed to respond honestly and to base their ratings on the student's usual behavior rather than exceptional performances. To minimize response bias, the research team emphasized confidentiality and clarified that all data would be used solely for research aimed at improving instructional support. After completing the forms, researchers immediately reviewed the questionnaires to ensure completeness and address any remaining uncertainties.

#### 2.5. Data Analysis

The measurement model was estimated using Maximum Likelihood (ML) in IBM SPSS AMOS after examining univariate distributions, multivariate normality, and outliers to ensure data adequacy. Although the Likert-type items were ordinal, they were treated as continuous because they contained five response categories, and this decision is noted as a limitation. Subsequently, Confirmatory Factor Analysis (CFA) was conducted to evaluate the four latent constructs (MIW, PAD, ILE, APM) and their indicators to ensure the validity and reliability of the measurement model [48].

Each indicator was specified to load on its intended latent factor, and the four latent variables were allowed to correlate, reflecting the theoretical interrelatedness of difficulties and supports [40], [49]. No cross-loadings were permitted, in line with the hypothesized measurement structure. Model fit was evaluated using  $\chi^2$  (df, p), CFI, TLI, RMSEA, and PNFI, with greater emphasis placed on CFI, TLI, and RMSEA due to the well-known sample-size sensitivity of the  $\chi^2$  statistic [50]. Model fit was considered acceptable when CFI and TLI were  $\geq 0.90$ , RMSEA was  $\leq 0.08$  and PNFI were  $\geq 0.50$  [51], [52]. When these criteria were not met, theoretically justified model specifications were undertaken, guided by modification indices and the pattern of factor loadings [49].

Construct validity was ensured by examining reliability and convergent validity. Reliability was assessed using Cronbach's alpha  $\geq 0.70$  [53]. Standardized factor loadings  $\geq 0.50$  were considered acceptable, and  $\geq 0.70$  were considered desirable for well-defined constructs [54]. Items with loadings  $< 0.40$  were flagged as candidates for revision in future refinement. In addition to these measures, Composite Reliability (CR) was calculated, with a threshold of CR  $\geq 0.70$  indicating good internal consistency of the constructs [39]. Furthermore, the Average Variance Extracted (AVE) was assessed, with an acceptable value of AVE  $\geq 0.50$  indicating adequate convergent validity. Together, these procedures ensured that the four latent constructs were measured reliably and in accordance with the proposed theoretical framework.

### 3. RESULTS

#### 3.1. Demographic information

Demographic information was recorded to characterize the sample. Most participants were children in early elementary grades who demonstrated varying levels of motor limitations typical of Cerebral Palsy, particularly in fine-motor precision, grip stability, and hand–eye coordination [55], [56]. Focusing exclusively on students with CP allowed the study to address the specific pre-writing challenges prevalent within this population, which differ substantially from those of students with other disabilities.

The participants' demographic characteristics provide essential context for interpreting the CFA results. Most

respondents were children aged 9–12 years with Spastic Cerebral Palsy and moderate motor impairments, conditions known to affect fine-motor coordination, hand control, and early writing readiness. This profile aligns closely with the constructs examined in the CFA, which target core pre-writing skill components that are typically affected in children with CP. The high proportion of students with functional or partially functional dominant-hand use further supports the suitability of the measurement model, as the assessed skills require basic hand manipulation. Additionally, the concentration of participants in early and middle elementary grades aligns with the developmental period when pre-writing skills are actively forming.

**Table 5.** Demographic Characteristics of Respondents (N=108)

Demographic	Category	Frequency	Percentage (%)
Age Group	6–8 years	18	16.67%
	9–10 years	45	41.67%
	11–12 years	45	41.67%
Type of Cerebral Palsy	Spastic CP	90	83.33%
	Dyskinetic/Athetoid CP	0	0.00%
	Ataxic CP	0	0.00%
	Mixed Type	18	16.67%
Motor Impairment Severity	Mild	0	0.00%
	Moderate	108	100.00%
	Severe	0	0.00%
Dominant Hand Function	Functional	72	66.67%
	Partially functional	36	33.33%
	Non-functional	0	0.00%
Educational Level	Early elementary (Grades 1–2)	63	58.33%
	Middle elementary (Grade 3–4)	45	41.67%
	Upper elementary (Grade 5–6)	0	0.00%
Learning Stage	Pre-writing skills	108	100.00%

**Table 6.** Descriptive Statistical Analysis

Construct	Item	Mean	Std. Deviation	Skewness	Kurtosis
Motor Impairment to Writing (MIW)	MIW1	4.095	0.826	-1.187	1.831
	MIW2	4.250	0.730	-1.248	2.915
	MIW3	4.225	0.723	-1.116	2.213
	MIW4	4.140	0.811	-1.161	1.860
	MIW5	4.195	0.760	-1.272	2.508
Pre-Writing Activity Difficulties (PAD)	PAD1	4.110	0.738	-1.189	2.899
	PAD2	4.100	0.745	-1.218	3.018
	PAD3	4.170	0.787	-1.127	1.821
	PAD4	4.045	0.852	-1.107	1.545

Construct	Item	Mean	Std. Deviation	Skewness	Kurtosis
Inclusive Learning Environment (ILE)	PAD5	4.065	0.840	-1.217	1.956
	PAD6	4.065	0.765	-0.999	1.810
	ILE1	3.825	0.830	-0.957	1.139
	ILE2	3.910	0.812	-1.037	1.487
	ILE3	3.960	0.828	-1.100	1.579
	ILE4	3.900	0.817	-0.994	1.341
Adaptive Pre-Writing Media (APM)	ILE5	3.960	0.875	-0.923	0.869
	ILE6	4.045	0.804	-1.099	1.824
	APM1	4.095	0.765	-1.030	1.583
	APM2	4.125	0.768	-1.096	1.761
	APM3	4.075	0.805	-1.014	1.328
	APM4	4.075	0.796	-0.941	1.050
	APM5	4.140	0.745	-1.284	3.045
	APM6	4.225	0.730	-1.114	1.968

Table 6 presents the descriptive statistics for the four constructs, showing that all items exhibit negative skewness, indicating that most responses clustered at the higher end of the scale, typical of Likert-type instruments. The kurtosis values are positive, suggesting a leptokurtic distribution where responses are concentrated around the mean, indicating limited dispersion. Specifically, skewness values range from -0.941 to -1.284, while kurtosis values range from 0.869 to 3.045, with some items like MIW2 and APM5 showing

particularly high kurtosis values, indicating a strong concentration of responses around the mean. This distribution characteristics, along with the high reliability values, demonstrate strong data consistency and a general tendency toward positive perceptions among respondents. The data shows that participants consistently rated the items positively, with minimal variability in their responses, reflecting a uniform and favorable attitude toward the constructs measured.

**Table 7.** Validity and Reliability

Constructs	AVE	C.R.	Cronbach's Alpha
Motor Impairment to Writing (MIW)	0.539	0.853	0.884
Pre-Writing Activity Difficulties (PAD)	0.583	0.892	0.889
Inclusive Learning Environment (ILE)	0.646	0.899	0.865
Adaptive Pre-Writing Media (APM)	0.616	0.823	0.892

**Table 8.** Goodness of Fit (GOF)

Criteria	Threshold	Value	Results	Sources
Probability (p)	$\geq 0.050$	0.427	Fit	[40], [57]
Chi-Square (CMIN/DF)	$< 2.000$	1.014	Fit	[58], [59]
Root Mean Squared Error of Approximation (RMSEA)	$< 0.080$	0.007	Fit	[51], [52], [59]–[61]
Tucker Lewis Index (TLI)	$> 0.900$	0.997	Fit	[59], [62]
Comparative Fit Index (CFI)	$> 0.900$	0.998	Fit	[52], [63] [59]
Parsimony Normed Fit Indices (PNFI)	$> 0.500$	0.786	Fit	[64] [52]

Table 7 presents the validity and reliability results for four constructs measured in this study. All constructs have Average Variance Extracted (AVE) values above 0.50, indicating good convergent validity, meaning the items within each construct are strongly related. Additionally, the Composite Reliability

(CR) and Cronbach's Alpha values for each construct show excellent internal consistency, as all CR and Cronbach's Alpha values exceed the threshold of 0.70, with the highest value reaching 0.899 for Inclusive Learning Environment (ILE). These results demonstrate that the constructs measured in

this study are both reliable and valid, with consistent and accurate measurements in alignment with the proposed theoretical framework.

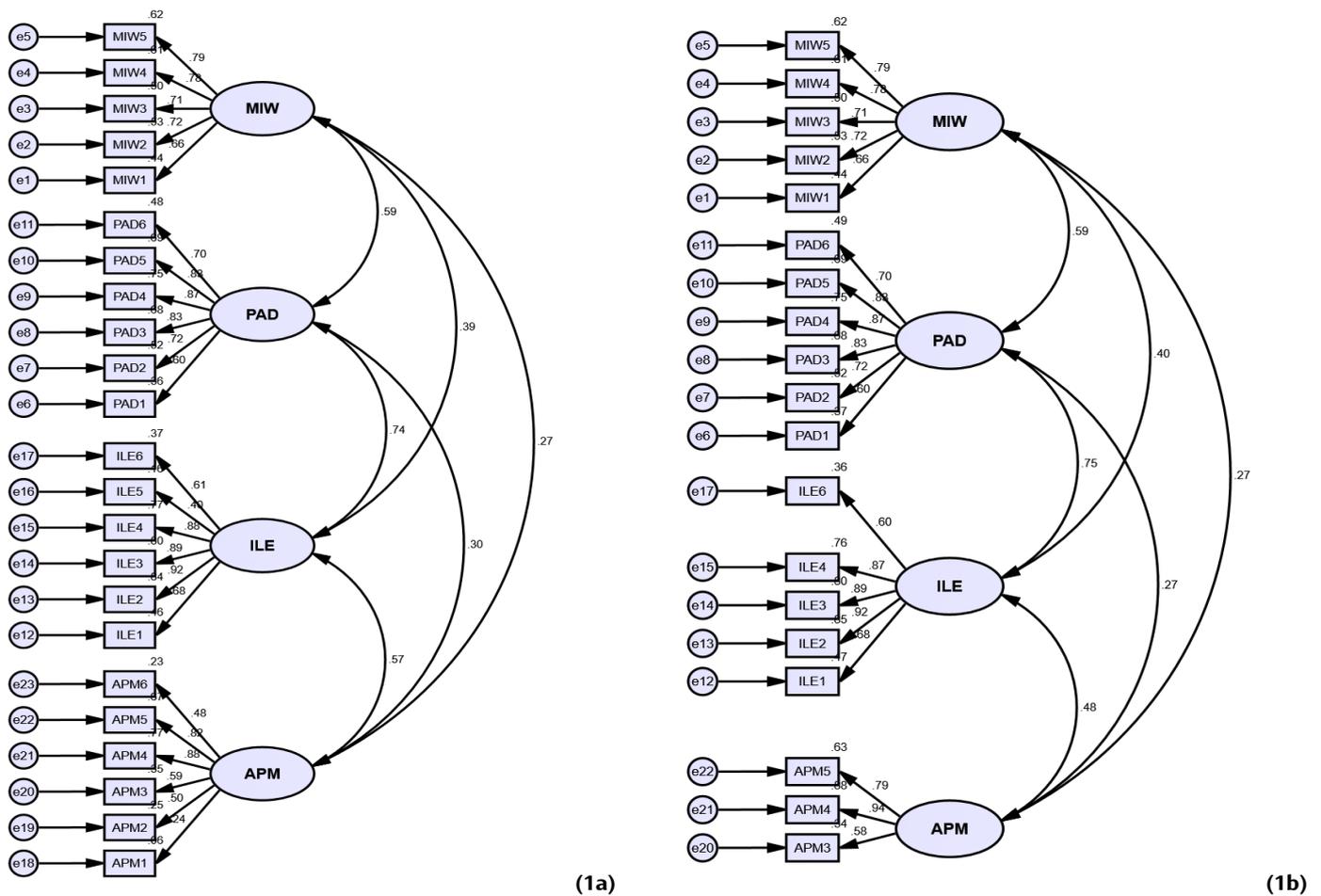
**3.2. Goodness of Fit**

The results of the goodness-of-fit assessment (Table 8). All indices met their respective cut-off criteria, demonstrating that the final measurement model achieved a satisfactory fit to the data. Specifically, the nonsignificant  $\chi^2$  probability ( $p = 0.427$ ) and the low  $\chi^2/df$  ratio (1.014) indicate strong absolute fit. Incremental fit indices also exceeded recommended thresholds, with TLI = 0.997 and CFI = 0.998, reflecting excellent comparative fit. The RMSEA value of 0.007, well below the 0.08 criterion, further confirms a close fit between

the model and the data. Additionally, the PNFI value of 0.786 surpasses the recommended parsimony fit threshold ( $> 0.50$ ), supporting the model's adequacy while accounting for model complexity.

**3.3. Confirmatory Factor Analysis (CFA)**

The CFA was conducted in two stages to evaluate the measurement model. The initial model (Figure 1a) included all proposed indicators for the four latent variables (MIW, PAD, ILE, APM). This model was assessed to determine whether each indicator adequately represented its intended construct based on standardized factor loadings. Indicators that failed to meet these criteria were removed, and the revised structure is shown in Figure 1b.



**Figure 1.** Initial (1a) and final (1b) four-factor CFA models for motor impairment to writing (MIW), pre-writing activity difficulties (PAD), inclusive learning environment demands (ILE), and adaptive pre-writing media (APM). Standardized factor loadings are shown for the final model.

**Table 9.** Standardized Regression of Estimate in the CFA Model

			Estimates	S.E.	C.R.	P
MIW1	<---	Motor Impairment to Writing (MIW)	0.663	0.074	13.578	***
MIW2	<---	Motor Impairment to Writing (MIW)	0.725	0.079	13.675	***
MIW3	<---	Motor Impairment to Writing (MIW)	0.710	0.092	12.885	***
MIW4	<---	Motor Impairment to Writing (MIW)	0.779	0.103	13.489	***

			Estimates	S.E.	C.R.	P
MIW5	<---	Motor Impairment to Writing (MIW)	0.786	0.108	13.674	***
PAD1	<---	Pre-Writing Activity Difficulties (PAD)	0.604	0.086	11.675	***
PAD2	<---	Pre-Writing Activity Difficulties (PAD)	0.719	0.085	12.736	***
PAD3	<---	Pre-Writing Activity Difficulties (PAD)	0.826	0.105	13.780	***
PAD4	<---	Pre-Writing Activity Difficulties (PAD)	0.866	0.109	14.121	***
PAD5	<---	Pre-Writing Activity Difficulties (PAD)	0.833	0.127	13.748	***
PAD6	<---	Pre-Writing Activity Difficulties (PAD)	0.698	0.085	12.432	***
ILE1	<---	Inclusive Learning Environment (ILE)	0.683	0.078	12.862	***
ILE2	<---	Inclusive Learning Environment (ILE)	0.924	0.090	18.192	***
ILE3	<---	Inclusive Learning Environment (ILE)	0.893	0.088	17.392	***
ILE4	<---	Inclusive Learning Environment (ILE)	0.869	0.104	17.095	***
ILE6	<---	Inclusive Learning Environment (ILE)	0.598	0.080	12.049	***
APM3	<---	Adaptive Pre-Writing Media (APM)	0.585	0.088	11.342	***
APM4	<---	Adaptive Pre-Writing Media (APM)	0.937	0.137	13.339	***
APM5	<---	Adaptive Pre-Writing Media (APM)	0.793	0.150	12.628	***

Note: \*p < 0.05; \*\*p < 0.01; \*\*\*p < 0.001

The initial CFA results indicated that several indicators had standardized factor loadings below the recommended cut-off of 0.50, suggesting that they did not adequately capture the variance of their respective latent constructs [65]. Accordingly, indicators APM1, APM2, APM6, and ILE5 were removed from the measurement model. The re-estimated final model showed higher factor loadings and improved measurement properties, indicating that the retained indicators provided a more reliable and valid representation of the four constructs [64].

Based on Table 7, all standardized factor loadings (0.585–0.937) exceed the recommended threshold of 0.50 and are statistically significant at  $p < 0.001$  (C.R. > 1.96). These results confirm that the retained indicators (MIW1–MIW5, PAD1–PAD6, ILE1–ILE4, ILE6, and APM3–APM5) function as valid measures of their respective latent constructs and, collectively, meet the requirements for convergent validity. The indicators with the strongest contributions MIW5, PAD4 and PAD5, ILE3 and ILE4, and APM4 further enhance the model's measurement precision and explanatory power.

Eliminating indicators with low factor loadings during the initial estimation phase (APM1, APM2, APM6, and ILE5) substantially improved the psychometric soundness of the measurement model. This refinement process ensured that only the most reliable and theoretically coherent indicators were retained. As a result, the final CFA model demonstrates robust construct validity and can be regarded as a reliable, well-specified, and empirically supported representation of the four latent constructs examined in this study.

#### 4. DISCUSSIONS

This study validated a four-factor measurement model describing the interplay among motor impairment to writing

(MIW), pre-writing activity difficulties (PAD), an inclusive learning environment (ILE), and adaptive pre-writing media (APM) among children with cerebral palsy (CP). The excellent model fit indices ( $\chi^2/df = 1.014$ ; CFI = 0.998; TLI = 0.998; RMSEA = 0.007; PNFI = 0.786) demonstrate that the hypothesized model is statistically sound and theoretically consistent with multidimensional conceptualizations of functioning based on the ICF-CY. High and significant factor loadings (> 0.50) further confirm the convergent validity of the constructs, supporting prior work emphasizing the multidimensional nature of motor, activity, and environmental factors in determining functional outcomes for children with CP [4], [66].

The scale also demonstrated excellent reliability, with Cronbach's alpha values exceeding 0.86 for all constructs. These findings align with earlier instrument-validation studies showing that teacher-observation-based assessments can reliably capture functional performance in school contexts, particularly when grounded in established frameworks such as HAAT and ICF-CY [67]–[69]. High reliability is crucial for educational planning and therapeutic decision-making, as inconsistent measurements may lead to inappropriate instructional strategies or misidentification of student needs.

Descriptive results indicate that students with CP experience substantial difficulties in fine-motor coordination, tool grasp, posture, and hand-eye coordination skills essential for pre-writing readiness. These findings echo numerous studies documenting that neuromotor impairments in CP significantly disrupt graphomotor development, handwriting fluency, and early literacy acquisition [3], [70]. Moreover, the observation that teachers frequently endorse these difficulties underscores the need for systematic instructional scaffolding and adapted motor training.

The strongest inter-factor correlation emerged between PAD and ILE ( $r = 0.754$ ), highlighting those environmental demands including instructional pacing, time constraints, and classroom physical arrangement play a major role in determining successful participation in writing activities. This pattern aligns with the ICF-CY model, which emphasizes that disability arises from the interaction between impairments and contextual barriers rather than from impairments alone [71]. The findings also support UDL principles advocating flexible, accessible instructional approaches to accommodate diverse learners [72]. Studies in inclusive classrooms consistently show that environmental modifications significantly enhance engagement and task performance among students with motor impairments [73]–[75].

Moderate correlations between MIW and PAD ( $r = 0.587$ ) confirm that while motor impairment contributes to pre-writing challenges, performance is also shaped by practice opportunities and environmental scaffolding. This is consistent with intervention studies showing that motor impairments can be mitigated through structured, task-specific training, occupational therapy, and motor-learning approaches [76], [77].

Meanwhile, the correlation between ILE and APM ( $r = 0.481$ ) suggests that inclusive classroom ecology tends to support the use of adaptive media, including assistive technologies and modified tools. This mirrors the HAAT model's emphasis on aligning technology use with human abilities and activity demands [78], [79]. Research in low-resource settings, including Indonesia, shows that successful integration of assistive technology depends greatly on teacher training, administrative support, and cross-sector collaboration [80].

Lower correlations between APM and both MIW and PAD indicate that adaptive tools may not yet be implemented intensively or specifically enough to fully compensate for motor and activity limitations. This gap is widely reported in LMIC contexts where assistive technology availability is low and teacher preparation is uneven [81], [82]. These findings underscore the need for tailored, evidence-based implementation of adaptive pre-writing media.

Interestingly, two indicators within the assistive and physical environment domain APM1 (adjustable furniture) and APM2 (specific assistive tools) were excluded from the final model due to consistently low factor loadings. This pattern likely reflects a pronounced floor effect, as such resources are largely absent in the sampled low-resource schools, resulting in insufficient variability for these items to capture meaningful differences in environmental support. Their removal therefore strengthened the overall model fit while simultaneously highlighting structural inequities in assistive provision within the educational context.

The high correlation between PAD and ILE also suggests partial measurement overlap rather than a purely substantive relationship. Several ILE items were phrased in terms of students' observable task difficulties instead of explicit classroom features such as pacing, task structure, or accessibility. This wording likely inflated the association between the two constructs and limited the instrument's ability to clearly distinguish activity limitations from

environmental demands. Future revisions should refine ILE indicators to operationalize environmental characteristics more directly.

These findings must further be interpreted in light of the sample characteristics, which consisted solely of students with moderate motor impairments enrolled in special schools within a single urban area. As such, the factor structure and inter-factor relationships may differ among students with milder or more severe CP, those placed in mainstream inclusive classrooms, or populations in other cultural and educational contexts. Replication across diverse settings and disability profiles remains essential for establishing the robustness of the proposed model.

## 5. IMPLICATIONS

Practically, the validated four-factor structure reinforces multidimensional views of pre-writing readiness that integrate body functions, activity demands, and contextual supports as described in the ICF-CY, HAAT, and UDL frameworks. The moderate-to-strong correlations among MIW, PAD, and ILE suggest that interventions targeting motor skills alone may be insufficient without simultaneous adaptation of classroom demands and supports. The study advances measurement research by integrating the ICF-CY, HAAT, and UDL frameworks within a Southeast Asian educational context, addressing calls for culturally relevant assessment tools in special education [83], [84].

For practitioners, the instrument offers a structured way to identify whether a student's pre-writing difficulties are primarily driven by motor impairments, task characteristics, environmental demands, or insufficient adaptive media. This can inform individualized education plans (IEPs), guide collaboration between teachers and therapists, and support resource allocation for assistive technologies in low-resource settings.

## 6. LIMITATIONS

The study's limitations include its cross-sectional design, reliance on teacher reports, and limited generalizability to broader populations. Future research should employ longitudinal designs and performance-based measures to examine predictive relationships with handwriting outcomes, academic achievement, and overall participation. Additionally, incorporating clinical assessments, student self-reports, and digital handwriting analytics could further strengthen the validity evidence and provide a more comprehensive understanding of the factors influencing pre-writing development.

## 7. CONCLUSION

This study provides initial evidence for a robust four-factor model capturing motor impairments, pre-writing activity difficulties, classroom demands, and adaptive media among students with CP in Indonesian special schools, with strong

model fit and high reliability indicating its potential as a practical tool for school-based assessment of pre-writing readiness. However, the partial overlap between activity-related and environment-related indicators suggests the need for refining the ILE construct to represent environmental dimensions more precisely. Future research should validate the model across diverse regions and mainstream inclusive classrooms, examine its longitudinal predictive value for handwriting and early literacy outcomes, and incorporate performance-based and student-reported measures to strengthen construct validity and enhance its applicability for monitoring academic participation.

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## Conflicts of Interest

The authors declare that no conflicts of interest are associated with this study. All aspects of the research were conducted with the utmost integrity and transparency.

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