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Development and validation of assessment tools for literacy and numeracy skills in early childhood education

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ABSTRACT

This study focuses on developing and validating a tool to assess literacy and numeracy skills in young children. A total of 137 children from five kindergartens participated. The tool was first evaluated for content validity through a review of existing literature and further refined by expert feedback. Then, its construct validity was examined using exploratory factor analysis, and its reliability was assessed using McDonald's Omega (ω) and Cronbach's alpha coefficient (α). The data were analyzed using SPSS to confirm the validity and reliability of the tool for each skill set. Both literacy and numeracy components showed high validity with a p-value of 0.000. The reliability for the literacy tool was also high, with Cronbach's alpha and McDonald's Omega both around 0.797. For the numeracy tool, reliability was acceptable, with Cronbach's alpha at 0.713 and McDonald's Omega at 0.705. The results confirm that the questionnaire is a valid and reliable instrument for evaluating literacy and numeracy skills in early childhood. This research contributes to the creation of two tools that can aid educators in various institutions interested in enhancing literacy and numeracy education at the kindergarten level. Further exploration of additional aspects is suggested for future research.

1. Introduction

Literacy learning for children begins long before the child enters formal school (Niklas et al., 2016) as a preliminary milestone that has an impact on a child's future development (Morrison, 2007). Furthermore, children gain the most valuable learning experiences that influence their lives in the future when they are between 0-8 years old (Aljojo et al., 2019; Dewi et al., 2020). They use language orally or in writing to communicate, assuming the existence of an audience and the meaning of the communicative action characterized by spoken and written language activity.

In various ways, teachers and parents can support young children in stimulating the use of language for various purposes. This may encourage them to recognize language patterns that will help them in their literacy development later in life (Raban and Scull, 2013).

Many children may have difficulty reading (Dicataldo et al., 2022) because their literacy skills are not developed early in childhood. Oral language skills, which include using vocabulary expressively and understanding codes and symbols (such as phonological awareness), are closely linked to early literacy. Therefore, it is very important for children to develop the ability to understand and use language expressively from an early age (Whitehurst and Lonigan, 1998). Therefore, many studies with various interventions only use expressive or receptive vocabulary development as a learning outcome (Dicataldo et al., 2022; Senechal and Cornell, 1993). Children's early language abilities usually include both receptive and expressive skills. Receptive language skills involve understanding spoken language, such as listening comprehension. Expressive language skills involve speaking abilities, such as using vocabulary and forming sentences. These two types of language skills are closely related and remain relatively stable from early childhood onwards (Niklas et al., 2016; Wirth et al., 2022). Words should be broken down into smaller segments to differentiate similar sounding parts,

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helping to build the foundation for later phonological awareness skills.

Gandolfi et al. (2021) emphasized the interference found related to oral language skills, especially expressive vocabulary, which may have a significant indirect function in enhancing early literacy skills. Currently, it is widely believed that spoken language is the basis of written language, and spoken language skills make an important contribution to literacy learning (Raban and Scull, 2013). The first step for children to become active speakers is to listen passively. This then develops into nonverbal communication. Differences in how well children can segment speech signals can predict their future language development (Newman et al., 2006; Niklas et al., 2016).

In addition, any early years assessment carried out also reveals the curriculum intended or implemented to assess children's achievement based on what they learn (Gee, 2003; Scull et al., 2021).

Early numeracy skills are very important for later academic performance (Vessonen et al., 2023). Early education plays a crucial role in developing these skills, including quantitative reasoning, number recognition, and problem-solving abilities (Aunio et al., 2014a; 2014b; Bryant and Nunes, 2002). Numeracy is defined as 'the capacity, confidence, and disposition to use mathematics to meet the demands of learning, school, home, work, community, and civic life' (Papic et al., 2013). Each child has different counting skills, and these differences are noticeable early in childhood and become more pronounced over the years (Manolitsis et al., 2013; Zhang et al., 2020). Educators can support and encourage children as they develop mathematical concepts and skills by using various methods and contexts to document and assess their learning.

The Program for International Student Assessment (PISA) results, announced on December 5, 2023, ranked Indonesia 68th. Indonesian students scored 371 in literacy and 379 in mathematics. In 2012, Indonesia was among the bottom 10 of 65 participating countries (Novarianing Asri et al., 2017). The lack of early childhood national assessments partly explains why literacy and numeracy skills have not improved. This low achievement may affect children's overall mathematical abilities. Research (Triwahyuni et al., 2020) shows that students who read well are more likely to succeed in school (Grünke, 2019), while those with poor reading comprehension are more likely to leave school without qualifications (Hernandez, 2011). To evaluate early numeracy skills in children, a reliable assessment tool that works in all conditions is needed (Drost, 2011). Early childhood assessments are done through observation, recording, and documenting children's learning performance, with educators playing a key role (Tayler and Ishimine, 2013). Researchers have highlighted the need for suitable assessment tools that consider direct observations of children during natural learning activities (Clay, 2019). Ideally, this involves regular observations of children performing various tasks that showcase multiple skills rather than relying on a single test (Scull et al., 2021). Consistent tests can identify differences among individuals over time. The reliability of a test depends on its repeatability across different people, occasions, conditions, and instruments meant to measure the same thing (Drost, 2011). Early childhood education can adapt its practices based on the environment's characteristics while still following the government-set minimum curriculum (MOE, 2022).

2. Method

This research follows the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines, which are widely accepted for improving review quality and reproducibility (Moher et al., 2009). Articles were searched using "publish or perish" with the keywords "literacy on early children" and "numeracy on early children" indexed by Scopus. The process involved searching for relevant articles, selecting them, evaluating their quality, extracting data, and analyzing them to understand previous instruments. Then, the tool was developed and validated through expert judgment from five relevant experts. After expert validation, the questionnaire was tested on students over 14 days. Based on Cheung et al. (2018) and Yang et al. (2021), numeracy skills were assessed three times using number identification, rote counting, missing numbers, and simple addition. Teachers from five kindergartens worked with researchers to observe children's literacy and numeracy skills. Finally, statistical analysis, including Exploratory Factor Analysis (EFA) and reliability tests using McDonald's omega and Cronbach's alpha, was conducted to ensure the instrument's internal consistency.

This study aims to design and validate tools to assess literacy and numeracy in children aged 5-6 years. To meet this goal, the tools will undergo content validation through a literature review and expert judgment and construct validation of the questionnaire. The multitrait-multimethod matrix method will be used to evaluate construct validity by examining both convergent and discriminant validity and considering how different methods affect the observed results (Campbell and Fiske, 1959; Strauss and Smith, 2009). One hundred thirty-seven children aged 5-6 years old (average age = 5.8 years, standard deviation = 0.71) participated in the study. The group included 55% boys (76 boys) and 45% girls (61 girls). The children were randomly selected from five kindergartens in urban areas.

The study used SPSS version 26 to perform statistical analysis and check construct validity with the EFA method. Cronbach's alpha (α) was used to confirm the questionnaire's internal consistency, with values above 0.70 considered acceptable (Cheung et al., 2023). McDonald's Omega was also calculated to ensure reliability without depending on estimates of factor loadings or error variances (Hayes and Coutts, 2020).

3. Results

3.1. Content validity of the literacy and numeracy questionnaire

Content validity, also known as definition or logical validity, is the extent to which selected items reflect the construct variables being measured. Newman et al. (2013) defined it as how well the items of an instrument represent the content domain. Initial efforts involved a systematic literature review to find, select, and evaluate relevant studies (Budianto et al., 2022). In this study, 177 documents on literacy and 40 articles on numeracy were examined. These documents were chosen based on title similarity using the "Publish or Perish" search engine on Scopus, following the PRISMA protocol with keywords “literacy in early childhood” and “numeracy in early childhood” for articles published between 2017 and 2023 (Fig. 1).

During the search and identification process, one corrigendum and five literacy articles could not be found. For numeracy, one article did not meet the requirements because it was not traceable. In the screening phase, 85 literacy articles and 15 numeracy articles were eliminated for reasons such as not being in the education field, not focusing on early childhood, or being specifically about children with disabilities. After reviewing reports and abstracts, 17 literacy articles and 7 numeracy articles were not retrievable. Ultimately, 69 literacy articles and 17 numeracy articles met the initial criteria, but further review showed many did not include the variables analyzed. Thus, 24 literacy articles and 10 numeracy articles were included in the final review. The literacy studies were mostly quantitative (21), with one qualitative, one mixed-method, one meta-analysis, and no systematic reviews. For numeracy, there were 8 quantitative studies, no qualitative or mixed-method studies, and 2 systematic reviews. The most common literacy dimensions identified were 1) Expressive skills, 2) Receptive abilities, and 3) Pre-reading skills. For numeracy, the dimensions were: 1) Numbers, 2) Patterns, 3) Data analysis, and 4) Measurement. These dimensions guided a detailed search using "Publish or Perish" to identify relevant items for the instrument. The identified dimensions for literacy and numeracy were then combined and refined to complete and enhance the assessment tool.

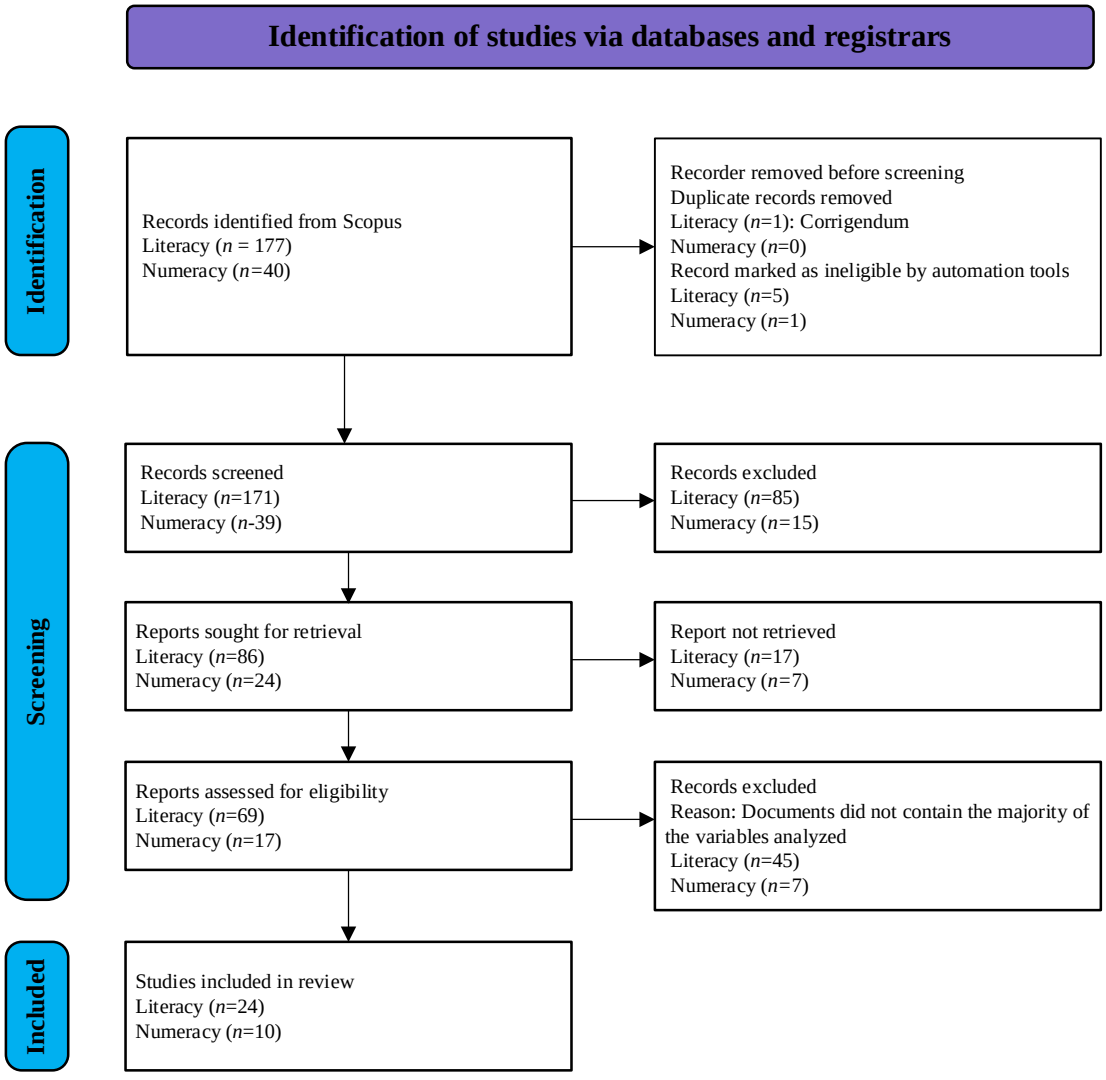

Fig. 1: PRISMA protocol

3.2. Validity of expert judgement

Expert judgment is a common method to determine the content validity of a questionnaire. It helps identify which items should be included to measure the intended construct. In this study, researchers reviewed existing items and adapted them to fit early childhood contexts. They based their evaluations on quantitative and qualitative criteria, suggesting changes to the wording as needed (Guillot-Valdés et al., 2022). This method is widely used to assess the content validity of new instruments (Leyton-Román et al., 2021). Experts were selected based on their educational background and area of expertise (Table 1).

Table 1: Expert judgement qualification

Purpose	Confirm in accordance with each item on the instrument
Expert 1	Professor of education science and expert in educational technology, especially generational differences and technology Integration in learning, instruction, and performance, wrote a book on research and development methods in education
Expert 2	Professor of educational science and expert in educational technology, especially the instructional design model
Expert 3	Doctor of education science and expert in early childhood education curriculum
Expert 4	Doctor of education science and expert in early childhood development assessment
Expert 5	Doctor of education science and expert in scaffolding, innovation, and research on education

Questions were asked to experts in relevant fields to ensure each item's suitability. The experts rated the instrument using a 5-point Likert scale with the following levels: a) Usable without revision, b) Usable with minor revisions, c) Usable with major revisions, d) Does not meet the criteria, and e) Cannot be used. Experts could also provide comments and suggestions for each item.

From the experts' feedback, it was concluded that the instrument could be used with minor revisions. The experts suggested changes to the 11 literacy items and 10 numeracy items, adding more detail to the numeracy items. They also ensured the wording was clear and easy for educators to understand.

3.3. Construct validity of the literacy questionnaire

After confirming content validity through expert judgment and using the PRISMA protocol, the next step was to select 137 children aged 5-6 years from five schools in Serang, a small city in Indonesia. The learning activity was themed "under the sea." This sample was used for construct validation.

First, an EFA was performed. The Kaiser-Meyer-Olkin (KMO) measure was 0.735, indicating that the variables could be predicted from each other, and Bartlett's test of sphericity (X2 = 425.787; df = 55; p-value = 0.000) was significant.

The community analysis showed values between 0.411 and 0.925, which were suitable for factor structure analysis. Using principal component analysis with Promax rotation, 11 items were grouped into three components, explaining 57.748% of the variance. The first factor explained 34.514% of the variance and included five items related to expressive language skills. The second factor explained 12.724% and included three items related to receptive language skills. The third factor explained 10.510% and included three items related to pre-reading skills. The statistical values in Table 2 show the relevance and appropriateness of the EFA implementation.

Table 2: EFA component matrix for literacy questionnaire

	Component		
	1	2	3
Asking about the sea	.411		
Making statements about aquatic animal	.725		
Telling a simple story about his experience raising aquatic animals	.807		
Expressed their feeling today	.816		
Singing about fish	.642		
Imitating the movements of the fish		.553	
Holding/touching alphabet materials		.615	
Recognizing the sound of the initial letters of the object name		.925	
Write their own name			.651
Listening to others			.831
Write the word "fish"			.584

Extraction method: Principal component analysis; Rotation method: Promax with Kaiser Normalization (Rotation converged in 6 iterations)

3.4. Reliability of the literacy questionnaire

Reliability was measured using McDonald's Omega (W) and Cronbach's alpha (α), which are commonly used to assess instrument reliability. The overall reliability of the literacy instrument was acceptable (α = 0.795; W = 0.797). Additionally, reliability for each dimension was as follows: expressive skills (5 items; α = 0.758; W = 0.771), receptive skills (3 items; α = 0.628; W = 0.664), and pre-reading skills (3 items; α = 0.582; W = 0.623).

3.5. Construct validity of the numeracy questionnaire

This study conducted an EFA for the numeracy questionnaire to ensure that each item fit our design and needs. We used a sample of 137 children from five kindergartens in Serang, Indonesia, with a teacher for every 10-11 children. The EFA was performed using the KMO measure of 0.599, which indicates how well the variables can be predicted from each other, and Bartlett's test of sphericity (X2

= 299.324; df = 45; p-value = 0.000). The results showed that the EFA was suitable (Table 3). Community analysis indicated values above 0.4, ranging from 0.452 to 0.875, which were appropriate for the factor structure. Using principal component analysis with Promax rotation, 10 items were grouped into 4 components, explaining 65.843% of the variance. The first factor explained 29.655% of the variance and included three items related to numbering skills. The second factor explained 13.610% and included three items related to pattern skills. The third factor explained 11.613% and included two items related to data analysis skills. The fourth factor explained 10.964% and included two items related to measurement skills.

Table 3: EFA component matrix for numeracy questionnaire

	Component			
	1	2	3	4
Noticing numbers correctly	.624			
One-to-one correspondence	.723			
Cardinality	.818			
patterning by colors		.849		
patterning by shapes		.778		
Classifying the object patterns by size		.452		
Classifying the object patterns by physical characteristics			.771	
Arranging objects in order by height			.831	
Arranging objects in order by size				.875
concept of time				.660

Extraction method: Principal component analysis; Rotation method: Promax with Kaiser Normalization (Rotation converged in 6 iterations)

3.6. Reliability of the numeracy questionnaire

This study found that the numeracy instrument's reliability is generally acceptable (α = 0.713; W = 0.705). Additionally, the reliability for each dimension is as follows: numbering skills (3 items; α = 0.617; W = 0.668), pattern skills (3 items; α = 0.657; W = 0.729), data analysis (2 items; α = 0.417), and measurement skills (2 items; α = 0.432).

4. Discussion

The main goal of our research was to create a tool that can assess both literacy and numeracy skills at the same time. Previously, kindergartens in Serang, a small city in Indonesia, did not have such a tool. Teachers often did not use child development standards to create assessment indicators for these skills. The tool we developed includes eleven language skills (expressive skills, receptive skills, and pre-reading skills) and ten basic numeracy skills. These numeracy skills cover verbal counting, number identification, number naming, one-to-one correspondence, cardinality, patterns by size and color, shapes, data analysis (classifying objects by physical characteristics and height), and measurement (understanding time and size).

For children aged 5-6 in preschool, it is important to focus on numbers, measurement, geometry, algebra, patterns, and problem-solving. By age three, children can show quantities with their fingers (Stramel, 2021), a key early numeracy skill that predicts future mathematical abilities (Braak et al., 2022; Jordan et al., 2009).

To present accurate content validation, an analysis of scientific literature was carried out that reflects the actuality of research that has addressed the problem of this study from the start, with a focus on collecting data from various instruments for early childhood literacy (Bergman et al., 2021; Konishi et al., 2018; Korat et al., 2017; Liu et al., 2020; Lonigan et al., 2017; 2018; Markussen-Brown et al., 2017; Sampa et al., 2018; Scull et al., 2021; Wackerle-Hollman et al., 2020; Wirth et al., 2020; 2022; Xu et al., 2017) and various instruments for numeracy (Hellstrand et al., 2020; Korat et al., 2017; LeFevre et al., 2018; McLeod et al., 2019; Niklas and Tayler, 2018; Purpura and Lonigan, 2013; Raghubar and Barnes, 2017; Thomas et al., 2023; Wästerlid, 2022; Yang et al., 2021).

Before calculating statistics, the study first performs content validation to check how well the instrument covers the intended content. Validation looks at the content and structure of the instrument (Fraenkel et al., 2012). Expert judgment involves getting opinions from qualified individuals who have a strong track record in the field (Almanasreh et al., 2019). In this study, five experts were asked to assess the instrument and give their opinions on various aspects. These experts were chosen based on their research experience and expertise. They provided suggestions on the criteria, dimensions, and items of the instrument.

Our statistical analysis shows that most tasks for literacy and numeracy are acceptable. We used EFA to examine the factors underlying different task structures based on theoretical considerations. For literacy, the instrument was designed to test a two-factor model (expressive and receptive skills), but the analysis revealed three factors: expressive skills (Bergman et al., 2021; Konishi et al., 2018; Sampa et al., 2018), receptive skills (Liu et al., 2020; Markussen-Brown et al., 2017), and pre-reading skills such as letter knowledge, narrative skills, print awareness, and phonological awareness (Pan et al., 2017).

For numeracy, we initially tested a two-factor model focusing on data analysis and measurement, which are rarely assessed in kindergarten. Kindergarten children identify and describe characteristics of objects that can be measured, compare two objects to recognize differences and identify similarities (Stramel, 2021). Later, educators collaborated with researchers to develop instrument

items for two additional factors: algebra and pattern and numbering.

Our study has developed a valid and reliable tool for assessing literacy and numeracy skills in children aged 5-6 years. We designed and validated the instrument holistically, ensuring its reliability. To confirm validity, an external and objective criterion is necessary (Bolger and Wright, 1992). This research aimed to verify if the judgments made were accurate. We reviewed content validity, expert judgment, construct validation through EFA, and reliability analysis using McDonald's Omega and Cronbach's Alpha. The instrument showed positive results in all areas. The validation process followed the latest scientific literature from the past seven years (2017-2023) and used the PRISMA protocol with search terms "literacy on early children" and "numeracy on early children."

Using SPSS, we adjusted the suitability index of each item to ensure coherence, relevance, and clarity. This helped optimize the instrument based on assessments by experienced researchers in education and instrument validation. The construct validity showed positive values, supporting the appropriateness of the EFA. Community analysis and principal component analysis with Promax rotation and Kaiser showed positive values and an adequate factor structure. The correlations between dimensions were all positive, and the factor weights for each dimension confirmed the adequacy of each item.

5. Conclusions

In research, validity and reliability tests are crucial to ensure that instruments produce accurate and dependable results. This study addresses the need for valid and reliable tools to assess literacy and numeracy skills in children aged 5-6 years. The design, validation, and reliability checks were done to create a comprehensive tool for this purpose.

Future research could explore more detailed measures of literacy and numeracy skills, possibly using rating scales to assess the impact of interventions. The goal is to provide teachers with a suitable tool to evaluate children's skills. This study focused on essential literacy and numeracy skills for early childhood development. Future studies can develop instruments for other important areas, such as cognitive, social, and broader developmental skills.

5.1. Limitations

Although this study shows that our instrument is valid and reliable, it has several limitations. The concurrent validity is limited because teachers only slightly assessed children's numeracy skills, especially in data analysis and measurement, which each had only two assessment items. Additionally, we did not have information on how long the children had been studying in preschool. This could mean that teachers might rate children with similar performance levels differently. The study was conducted with children from five urban kindergartens, which may limit the generalizability of the findings. We acknowledge that the psychometric measurements might have some errors. Thus, early numeracy and literacy tools should be seen as additional evaluation tools, not replacements. While overall reliability was acceptable, some areas, like pre-reading skills, had lower reliability scores and needed further refinement. Despite these limitations, we hope this instrument will be helpful for early childhood educators in assessing literacy and numeracy development.

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Compliance with ethical standards

Ethical considerations

This study adhered to the highest ethical standards, ensuring voluntary participation with informed consent from the children's parents or guardians. The privacy and confidentiality of participants were strictly maintained, with anonymized data collection. The research was approved by the institutional review boards of Universitas Negeri Malang and Universitas Sultan Ageng Tirtayasa, minimizing risks and discomfort by designing child-friendly assessment tools. The study was funded by the Indonesia Endowment Funds for Education (LPDP) Center for Higher Education Funding (BPPT), ensuring unbiased outcomes and cultural sensitivity throughout the research process.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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