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Relationship Between Numeracy and Vocabulary Skills in Indonesian Preschool Children and the Impacts of Learning Environments

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Abstract

Although many studies on early childhood have been conducted, there is still a need for further research on numeracy and vocabulary skills, particularly in Indonesia. This research aims to confirm the correlation between numeracy and vocabulary skills in preschool children and to disentangle the effects of environmental factors on both numeracy and vocabulary skills. This research was conducted at Early Childhood Education and Care (ECEC) in the Jatinangor district and followed the principle of simple random sampling. Children were given numeracy and vocabulary tests, parents were asked to fill out a questionnaire about sociodemographic aspects and the learning environment in their homes, and teachers were asked to fill out a questionnaire about preschool activities concerning numeracy and vocabulary. Data were analyzed using a structural equation model with numeracy and vocabulary as outcome variables. Covariates such as age, gender and social status were also included in the model. The results of this study show that numeracy is closely linked to vocabulary skills and that only a specific preschool activity can explain the variance of numeracy. On the other hand, both home numeracy activities and a specific preschool literacy activity are significant predictors of vocabulary skills.

Keywords Numeracy · Vocabulary · Home learning environment · Preschool activities

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Résumé
Bien que de nombreuses études sur la petite enfance aient été menées, des recherches supplémentaires sur les compétences en calcul et en vocabulaire sont encore nécessaires, en particulier en Indonésie. Cette recherche vise à confirmer la corrélation entre les compétences en numératie et en vocabulaire chez les enfants d'âge préscolaire et à démêler les effets des facteurs environnementaux sur les compétences en numératie et en vocabulaire. Cette recherche a été menée à Early Childhood Education and Care (ECEC) dans le district de Jatinangor et a suivi le principe de l'échantillonnage aléatoire simple. Les enfants ont été soumis à des tests de numératie et de vocabulaire, les parents ont été invités à remplir un questionnaire sur les aspects sociodémographiques et l'environnement d'apprentissage à leur domicile, et les enseignants ont été invités à remplir un questionnaire sur les activités préscolaires concernant la numératie et le vocabulaire. Les données ont été analysées à l'aide d'un modèle d'équation structurelle avec la numératie et le vocabulaire comme variables de résultat. Des covariables telles que l'âge, le sexe et le statut social ont également été incluses dans le modèle. Les résultats de cette étude montrent que la numératie est étroitement liée aux compétences en vocabulaire et que seule une activité préscolaire spécifique peut expliquer la variance de la numératie. D'un autre côté, les activités de calcul à la maison et une activité spécifique de littératie préscolaire sont des prédicteurs significatifs des compétences en vocabulaire.

Resumen
Aunque se han llevado a cabo muchos estudios sobre la primera infancia, todavía se necesitan más investigaciones sobre las habilidades de aritmética y vocabulario, particularmente en Indonesia. Esta investigación tiene como objetivo confirmar la correlación entre las habilidades de aritmética y vocabulario en niños en edad preescolar y desentrañar los efectos de los factores ambientales en las habilidades de aritmética y vocabulario. Esta investigación se llevó a cabo en la Educación y Atención de la Primera Infancia (ECEC) en el distrito de Jatinangor y siguió el principio de muestreo aleatorio simple. A los niños se les realizaron pruebas de aritmética y vocabulario, se pidió a los padres que completaran un cuestionario sobre aspectos sociodemográficos y el entorno de aprendizaje en sus hogares, y se pidió a los maestros que completaran un cuestionario sobre actividades preescolares relacionadas con aritmética y vocabulario. Los datos se analizaron utilizando un modelo de ecuación estructural con aritmética y vocabulario como variables de resultado. También se incluyeron en el modelo covariables como la edad, el género y el estatus social. Los resultados de este estudio muestran que la aritmética está estrechamente relacionada con las habilidades de vocabulario y que solo una actividad preescolar específica puede explicar la variación de la aritmética. Por otro lado, tanto las actividades de aritmética en el hogar como una actividad de alfabetización preescolar específica son predictores significativos de las habilidades de vocabulario.

Introduction

Numeracy and language skills are two basic competencies that are closely related to the cognitive, social, and emotional development of children (Ebert et al., 2012). Both numeracy and language skills are evident to predict children's mathematics and reading abilities that have fundamental impacts on child development (Duncan et al., 2007). Accordingly, Clarke et al. (2016) have reported that interventions to improve preschool students' early numeracy skills increase mathematical abilities in subsequent years. Similarly, language skills also play a key role in various child developmental outcomes. A successful learning in academic subjects largely depends on a child's ability to understand oral and written language and children with language difficulties are at higher risk of having academic difficulties than children without language difficulties (Cross et al., 2019). One fundamental element of language is vocabulary (Storch & Whitehurst, 2002). Knowing many words and understanding the meaning of these words are associated with better language performance (Quines, 2022). The literature also documented that learners with big vocabularies are more proficient in a wide range of language skills than learners with smaller vocabularies (Meara, 1996).

Research on early childhood has confirmed that numeracy and vocabulary skills correlate significantly (Zhang et al., 2017). Children who have difficulties in vocabulary often also struggle in numeracy as well (Cross et al., 2019). More specifically, children's vocabulary abilities are a strong predictor for informal and formal mathematics skills (Zhang et al., 2017). Children with developmental language disorders as well as children who were English Language Learners have shown lower mathematics scores than mainstream children and English native children, respectively (Cross et al., 2019).

The learning environment is one factor that is repeatedly reported to influence children's development (Anders et al., 2012; Burgess et al., 2002; Ebert et al., 2012). The term learning environment refers to the learning process that occurs in social, physical, psychological, and pedagogical contexts and affects student achievement and attitudes (Fraser, 1998). Particularly for preschool children, the learning environment includes home and preschool characteristics and interactions of children with significant adults in a particular setting to support their development. Home learning environment refers to a variety of resources and opportunities provided to children, including parental skills, abilities, dispositions, and resources that regulate the occurrence of learning opportunities (Burgess et al., 2002). Therefore, a home learning environment includes parent–child activities such as parent–child joint reading as well as parents' expectations (Burgess et al., 2002). On the other hand, school learning environments include both global and domain-specific environments (Anders et al., 2012), which differ in their nature. While global environments include the culture of a school, its ethos, and features, as well as the strategies that teachers may use for teaching (Bates, 2019), the domain-specific environments involve stimulation in areas such as language, (pre)reading, numeracy, and scientific literacy (Kuger & Klucziok, 2009), which is often be observed in the preschools learning activities.

According to the literature in American and European countries, direct environments such as school and home have a significant role in supporting a child's numeracy and vocabulary skills (Anders et al., 2012; Burgess et al., 2002; Ebert et al., 2012). A home learning environment provides many opportunities for teaching and learning activities that support the development of children's numeracy and vocabulary skills. The home learning environment was a good predictor of early cognitive skills as well as competence at the end of elementary school even after controlling for antecedents, prior academic achievement, and child and family variables (Niklas & Schneider, 2017). Scarborough and Dobrich (1994) found a median correlation of 0.26 between parent–child joint reading activity during early childhood with reading ability both during early childhood and during elementary school. This value is high, considering that there is at least a two-year distance between preschool and elementary school. A meta-analysis of 29 studies on home learning environments found that differences in the level of exposure in preschool children can explain 8% of children's competence (Bus et al., 1995).

Furthermore, within the context of the school learning environment, learning content and methods, personal growth, an appropriate physical environment, and a favorable psychological environment are formed and designed (Lafond et al., 2007). A learning program at preschool could have a great impact on child development. For example, an experimental study in preschool students reported that the treatment group that obtained the MTSLS Program (Multitiered System of Language Support on Kindergarten Oral and Written Language using Story Champs) showed significantly higher improvements in vocabulary skills compared to the control group (Petersen et al., 2022). This program includes several preschool activities that support language development (Petersen et al., 2022). The preschool learning activities such as telling stories to students seem to enhance students' vocabulary, grammars, and comprehension (Petersen et al., 2022). Activities with children like singing and telling stories (using narratives that contain complex language and advanced vocabulary) can help students attend to greater detail, understand and use more complex vocabulary, understand and produce more complex syntax, and improve working memory (Montgomery et al., 2010).

Not only language activities but also physical activities (e.g., movement and outdoor activities or art activities) became significant interventions to improve numeracy and vocabulary skills. A study of 52 elementary students reported that embodied learning, which is a multimodal and playful process that requires the involvement of the human body in the cognitive process (Foglia & Wilson, 2013), enhances cognitive abilities and vocabulary skills (Kosmas et al., 2018). Specifically, the idea of embodied learning places the student in the center of the learning process, giving opportunities for physical interaction with the learning material (Chandler & Tricot, 2015) and providing hands-on activities in classroom-based environments.

According to Anders et al (2012), the quality of the home learning environment is a significant predictor for numeracy skills in the first to third year of preschool, while the process quality of the school is not related to numeracy skills in the first year of preschool. However, the process quality of the school can explain a substantial variance in numeracy skills in the second and third years of preschool. Prior studies in early childhood also documented that the effect of the school environment

on children's cognitive competence is only half or one-third of the effect of parenting on cognitive competence (NICHD, 2003). However, both school and home environments are significant determinants of child development, which explains up to 38% of the variance in children's numeracy and vocabulary growth (Anders et al., 2012; Ebert et al., 2012).

Unfortunately, information about the role of both home and school learning environments for children in the development of numeracy and vocabulary in Indonesia is still relatively limited. Although it seems only the problem of one country, there is still a need to inform the international readers as this may contribute not only to the development of science in general but also to the practical implications. It is most likely that some countries share some similarities with Indonesia and could benefit from this research report.

A lack of information about the determinants of the development of numeracy and vocabulary skills can inhibit the optimization of the learning environment to support children's cognitive development. This will in turn affect the development of children's numeracy and vocabulary skills. Therefore, it is imperative to examine the relationship between environmental factors and both numeracy and vocabulary skills in the Indonesian context.

Furthermore, since Indonesia has various local languages and many Indonesian children learn both Indonesian as official language and local language simultaneously, it is worth mentioning bilingualism as a relevant element of vocabulary acquisition. One important element to be discussed here is the competition model, which argues that a competition occurs between words from different languages but have the same referent (see Hernandez et al., 2005). A prior study suggested that there is a module created for each language and linguistic categories, which indicate a modular structure of languages and linguistics categories (see DevLex model in Li et al., 2004). The competition model basically argues that similar referent may cause competition between words from different languages, which are stored in different modules. If one of the languages obtains additional input from a supporting context, this language will win. This conception is not only true for vocabulary but also numeracy learning because both constructs are closely linked, particularly during early childhood (Zhang et al., 2017).

Current Study

This study aims to examine both the relationship between numeracy and vocabulary in Indonesian preschool children and the environmental factors that contribute to numeracy and vocabulary skills during early childhood. Based on the above-mentioned explanation, both numeracy and vocabulary skills are closely related and both home learning environment and preschool learning activities are assumed to determine both domains of competencies. However, research on vocabulary and numeracy in Indonesia is still relatively scarce. This research would provide empirical evidence regarding the relationship between numeracy and vocabulary as well as their predictors in Indonesian preschool children.

This study is conducted mainly to examine the following hypotheses:

Hypothesis 1 Numeracy during early childhood is significantly correlated with vocabulary.

Hypothesis 2 Home learning environments as well as preschool activities have valuable contributions in explaining the variance of numeracy of the children.

Hypothesis 3 Home learning environments as well as preschool activities are significant predictors of the vocabulary of the children.

Methods

Sample

A total of 191 preschool children (41% are girls) with a mean age of = 65.00 months and SD = 7.73 and their parents (either father or mother, mean age = 33.74 years and SD = 5.98, 88% are mothers) participated in this study. In addition, 22 preschool teachers (mean age = 34.09 years and SD = 10.73, 86% are women) also gave their responses to a questionnaire. Most of the preschool teachers have obtained their bachelor's degree in preschool education.

The sampling unit of this study was a preschool located in the Jatinangor district ($n = 9$). Based on random sampling analysis using Unpad SAS (Jatnika et al., 2021), the number of samples should be a minimum of 30 preschools. The research team invited 30 schools to participate in this study and obtained ten positive responses. However, due to time constraints, one preschool could not participate in this study.

This study has obtained an ethical clearance with registered number 2206070666 and ethical approval number is 906/UN6.KEP/EC/2022 from the ethics board of commission. The children were given numeracy and vocabulary tests, while parents and teachers were asked to fill out an online or a paper-based questionnaire about socio-demographics and the learning environments at home and school.

Instruments

Early Numeracy Test-Revised (ENT-R)

The initial numeracy ability measuring instrument used in this study is the ENT-R (Early Numeracy Test-Revised) version A (Toll & van Luit, 2014). This instrument was used to measure the level of mathematical competence of children from the age of four to seven years, which consisted of nine components that are indicators of early numeracy (i.e., concepts of comparison, classification, correspondence, seriation, use of numerals, synchronized and shortened counting, resultative counting, general understanding of numbers, and estimations). Each component contained five consecutive items. The total number of correct answers (0–45) was used in the analyses. The reliability coefficient of the test was good ($\alpha = 0.93$; van Luit & van de Rijt, 2009). In the current sample, internal reliability was also good ($\alpha = 0.91$). The

components, with instruction examples in parentheses, were concepts of comparison (here you see pencils; please point to the thickest pencil), classification (please point to all numbers that are larger than five and smaller than ten), correspondence (on this picture dots are displayed; please put down a similar amount of pawns), seriation (here you see boxes with marbles; please point to the box in which the marbles are arranged from smallest to largest), use of numerals (please count to twelve), synchronized and shortened counting (please watch this hand; [hand is covered] how many fingers were raised?), resultative counting (please make a row of eleven blocks), general understanding of numbers (the blue box contains nine chocolates, the yellow box thirteen; which box has the most chocolate?), and estimation (this is a line from zero to ten; please put the number 6 in the right position on this line).

Peabody Picture Vocabulary Test V (PPVT V)

In this study, the Peabody Picture Vocabulary Test V (PPVT V) (Dunn, 2019) was used to measure vocabulary. For each item, children were asked to choose one of four pictures that refer to a word that a test administrator pronounces. For example, when the test administrators pronounced "Ball," children needed to point to the picture "Ball" presented in the booklet along with other three distractor pictures. After 2 training items, several items of increasing difficulty were given. The start item number was based on the age until there were six consecutive correct responses (basal scores). The test is discontinued after consecutive failure on 6 items (ceiling score). Therefore, although the instrument consisted of 200 items, there was no exact number of items for all participants. The score was determined by the more correct answers given.

In this study, the original version of PPVT V was used, although there were some concerns about adapting a few items due to cultural differences. PPVT V has been used in various countries, and analysis of internal consistency of the Indonesian version yields a Cronbach's alpha of 0.98.

Home Learning Environment

The home learning environment was measured with two questionnaires that assessed both home numeracy and home literacy environments. Parents were administered these questionnaires after they submitted their consent for the participation of their children.

The home numeracy environment was assessed with a total of 11 items that consisted of six items concerning parents' numeracy expectations and five items concerning parent–child numeracy activities. The items of parents' numeracy expectations (e.g., "To what extent do you expect your child to have mastered the following skills at the end of preschool: addition till 10?") had a four-point Likert scale: not at all "1," a little "2," sufficient "3," and good "4." In contrast, the items of parent–child numeracy activities (e.g., "How often do you engage in the following activities together with your child: counting objects?") had a five-point Likert scale: hardly ever "1," weekly "2," a few times per week "3," daily "4," several times a day "5." The home numeracy environment questionnaire was

based on Kleemans et al. (2012). The original Dutch questionnaire showed a relatively good internal consistency with Cronbach's alpha of 0.92 and 0.79 for parents' numeracy expectations and parent–child numeracy activities, respectively (Kleemans et al., 2012). The Indonesian version showed a Cronbach's alpha of 0.88.

The home literacy environment was measured using a total of eight items that consist of three items concerning parents' literacy expectations and five items concerning parent–child literacy activities. The term literacy referred to acquiring, creating, connecting and communicating meaning in a wide variety of contexts (Alberta, 2010). The broad definition of literacy was suitable to access various activities that enhance vocabulary and language. The items of parents' literacy expectations (e.g., "To what extent do you expect your child to have mastered the following skills at the end of preschool: recognizing all letters a to z?") had a four-point Likert scale: not at all "1," a little "2," sufficient "3," and good "4." In contrast, the items of parent–child literacy activities (e.g., "How often do you engage in the following activities together with your child: reading a picture book?") had a five-point Likert scale: hardly ever "1," weekly "2," a few times per week "3," daily "4," several times a day "5."

The home literacy environment questionnaire was based on Peeters et al. (2009) and van der Schuit et al. (2009) frameworks about the importance of both parents' expectations and parent–child activities. Kleemans et al. (2012) examined the psychometric properties of the original Dutch questionnaire, which showed a Cronbach's alpha of 0.78 for both parents' literacy expectations and parent–child literacy activities. The psychometric properties of the Indonesian version showed good internal consistency with Cronbach's alpha of 0.84.

Preschool Activities

Preschool activities were measured by a paper-based teacher questionnaire that consisted of eleven items (e.g., "How frequently do you or other teachers carry out the following activities together with the children? [reading out, looking at picture books]"). Teachers were given these questionnaires on the first day of data collection and the filled out questionnaires were given back to the researcher team on the last day of data collection in the respective preschools.

In this study, we categorized the eleven items into six elements: (1) literacy (e.g., joint reading and looking at the books), (2) affection (e.g., hugging each other), (3) creativity (e.g., crafting, painting, and playing with playdough), (4) movement activities, (5) watching film or television, and (6) outdoor activities. The items have an eight-point Likert scale that ranges from never "1" to everyday "8." Teachers answered all questions about the preschool learning environment.

The questionnaire followed the items of learning environment proposed by the National Educational Panel Study (Blossfeld & Rossbach, 2019). The analysis of psychometric properties on the Indonesian version yielded a Cronbach's alpha of 0.72.

Demographic Factors

The demographic factors included the sex of both parents and children, parents' education measured by the last formal education accomplished by parents with a seven-point scale: the elementary school "1," junior high school "2," senior high school "3," diploma "4," bachelor's degree "5," master's degree "6," and doctoral degree "7." Parents were administered all items concerning the demographic factors.

Data Analysis

A structural equation model with two outcome variables was performed. Numeracy and vocabulary were regressed in the home numeracy environment; the home literacy environment; the preschool activities; and the covariates that were the age, sex of children, and the education of the parents. The indicators of numeracy were defined according to the nine components of early numeracy (see chapter 3.2.1), while an item parceling approach was used to determine the five indicators of vocabulary (see Matsunaga, 2008). The aim was to treat all learning environments as latent variables. However, the results showed a less optimal model fit. Therefore, home learning environments and preschool activities were treated as observed variables with multidimensional characteristics (see chapters 3.2.3 and 3.2.4).

The analysis was performed on RStudio version 1.3.959 (R Studio Team, 2020) using the lavaan package, version 0.6–7 (Rosseel, 2012). Model fit was assessed with the root mean square error of approximation (RMSEA), comparative fit index (CFI), and Tucker–Lewis index (TLI) (Kline, 2005).

Results

Descriptive Results

Descriptive results are presented in Table 1. Generally, there are some variances that could be observed within numeracy and vocabulary (see the standard deviation of both numeracy and vocabulary). The scores of both home numeracy and home literacy environments ranged from the lowest possible score to the highest, indicating that these constructs also had sufficient variances. In contrast, the range of scores of preschool activities such as literacy, affection, movement, and outdoor activities indicated that these activities were relatively often conducted in all preschools and, therefore, the score reached the possible highest score (i.e., 16, 16, 8, and 8 for literacy, affection, movement and outdoor activities, respectively) but not the possible lowest score (i.e., 2, 2, 1, and 1 for literacy, affection, movement and outdoor activities, respectively).

Correlational Results

The results of Pearson's correlation analysis are presented in Table 2. The correlation between numeracy and vocabulary was relatively high with $r = 0.57$, which

Table 1 Descriptive statistics

Variable	Mean (SD)	Min	Max	Percentage
Numeracy	20.75 (9.36)	0	45	
Vocabulary	95.16 (30.56)	20	179	
Home numeracy environment				
Numeracy expectations	20.68 (4.81)	6	24	
Numeracy activities	14.38 (4.92)	5	25	
Home literacy environment				
Literacy expectations	10.73 (2.12)	3	12	
Literacy activities	15.34 (4.43)	5	25	
Preschool learning environment				
Literacy	13.61 (2.34)	8	16	
Affection	12.68 (2.85)	5	16	
Creativity	17.99 (2.24)	13	21	
Movement	7.63 (.60)	6	8	
Watching film or television	5.34 (1.84)	1	8	
Outdoor activities	7.28 (.94)	5	8	
Age of children (in months)	65.00 (7.73)	48	82	
Sex of children				Girls = 41% Boys = 59%
Parent's education		1	6	1 = 5% 2 = 24% 3 = 41% 4 = 8% 5 = 18% 6 = 4%

$n = 191$. The possible scores of numeracy range from 0 to 45. The possible scores of vocabulary range from 0 to 200. The possible scores of home numeracy expectations range from 6 to 24. The possible scores of home numeracy activities range from 5 to 25. The possible scores of home literacy expectations range from 3 to 12. The possible scores of home literacy activities range from 5 to 25. The possible scores of literacy activities range from 2 to 16. The possible scores of affection range from 2 to 16. The possible scores of creativity range from 3 to 24. The possible scores of movement range from 1 to 8. The possible scores of watching films or television range from 1 to 8. The possible scores of outdoor activities range from 1 to 8. Parents' education: 1 = elementary school, 2 = junior high school, 3 = senior high school, 4 = diploma, 5 = bachelor's degree, 6 = master's degree, and 7 = doctoral degree

indicated that children with high numeracy skills were also very likely to have high vocabulary scores. Similar results were found for the correlations between home numeracy expectations and home literacy expectations as well as between home numeracy activities and home literacy activities, indicating that both numeracy and literacy learning environments were related to each other. Children who had high exposure to numeracy at home were most likely to have high exposure to vocabulary as well.

Interestingly, the correlations between home numeracy expectations and home numeracy activities as well as between home literacy expectations and home literacy activities seemed to be moderate in magnitude. More extreme results were found

Table 2 Bivariate Pearson analysis

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Numeracy														
2	Vocabulary	.57													
3	Numeracy expectations	.13	.13												
4	Numeracy activities	− .01	.09	.35											
5	Literacy expectations	.02	.03	.71	.33										
6	literacy activities	.01	− .04	.27	.63	.39									
7	Literacy	− .17	-.21	− .09	− .05	− .16	− .03								
8	Affection	− .11	.05	− .11	.01	− .22	.01	.32							
9	Creativity	− .13	− .01	− .13	− .00	− .21	− .01	.39	.85						
10	Movement	.15	.09	.15	− .03	.10	-.03	.03	.03	− .06					
11	Watching films or television	− .16	.04	− .16	− .03	− .12	.01	− .12	.59	.60	− .06				
12	Outdoor activities	− .12	− .13	− .12	− .01	− .19	− .06	.49	.45	.34	− .29	− .20			
13	Age of children	.39	.36	.07	− .08	− .02	.01	.12	.33	.28	.29	.23	− .19		
14	Sex of children	− .07	− .06	− .08	− .11	− .11	− .09	.08	.08	.04	-.05	.04	.02	.04	
15	Parents' education	− .21	− .08	− .21	.05	− .13	− .05	− .51	− .14	− .19	-.02	.02	− .09	− .29	− .01

$n = 191$

for the correlations between the indicators of preschool activities that range from -0.29 to 0.85, indicating that these indicators may not belong to a one-dimensional construct. Therefore, the analysis of the home learning environment and preschool activities was conducted using several indicators rather than one latent variable.

Analysis of Structural Equation Model

Overall, the model shows a relatively accepted fit with CFI = 0.94, TLI = 0.93, RMSEA = 0.06, and SRMR = 0.04. All factor loadings show accepted values, which range from 0.47 to 0.94. As mentioned in chapter 3.3., it was intended to treat both home learning environments and preschool activities as latent variables. However, the results show an unacceptable model fit and therefore we treated both home learning environments and preschool activities as multidimensional observable constructs.

Table 3 presents the results of a structural equation model with numeracy and vocabulary as outcome variables. Generally, the model explained about 30% and 26% variance of numeracy and vocabulary, respectively.

The covariation between numeracy and vocabulary yielded significant results with $B = 0.12$, $SE = 0.26$, $\beta = 0.48$ and $p = 0.00$, confirming hypothesis 1 about the relationship between numeracy and vocabulary skills of the children.

The only significant predictor for numeracy was activities related to movement in the preschool setting ($B = 0.23$, $SE = 0.10$, $\beta = 0.20$ and $p = 0.02$), and all home learning environments seemed not to have a statistically meaningful contribution to numeracy skills of the children.

Table 3 Regression analysis

	Numeracy			Vocabulary		
	B (SE)	*β*	*p*-values	*B (SE)*	*β*	*p*-values
Numeracy expectations	.02 (.01)	.17	.09	.08 (.10)	.08	.40
Numeracy activities	− .00 (.01)	− .03	.75	.18 (.09)	.18	.05
Literacy expectations	− .04 (.03)	− .13	.20	− .06 (.23)	− .03	.79
Literacy activities	.01 (.01)	.03	.72	− .19 (.10)	− .17	.06
Literacy	− .05 (.03)	− .16	.14	− .54 (.22)	− .25	.01
Affection	.00 (.04)	.02	.91	.28 (.31)	.16	.38
Creativity	− .05 (.04)	− .16	.25	− .03 (.31)	− .01	.93
Movement	.23 (.10)	.20	.02	− .32 (.70)	− .04	.65
Watching films or television	.01 (.05)	.03	.79	− .47 (.35)	− .17	.18
Outdoor activities	.10 (.10)	.14	.33	− .08 (.69)	− .01	.91
Age of children	.04 (.01)	.46	.00	.30 (.05)	.46	.00
Sex of children	− .09 (.10)	− .07	.34	− .57 (.70)	− .06	.42
Parents' education	.08 (.05)	.14	.12	.46 (.35)	.11	.19

$n = 191$

The results for vocabulary skills yielded two unexpected and interesting outcomes. First, while home literacy environments did not predict the vocabulary skills of the children significantly, the results produced a positive outcome for home numeracy activities ($B = 0.18$, $SE = 0.09$, $\beta = 0.18$ and $p = 0.05$). Second, preschool activities related to reading books seemed to predict vocabulary negatively ($B = -0.54$, $SE = 0.22$, $\beta = -0.25$ and $p = 0.01$), which means the more children did these activities in the preschool, the fewer vocabulary scores they had.

Furthermore, as expected, age correlated significantly with both numeracy and vocabulary skills ($B = 0.04$, $SE = 0.01$, $\beta = 0.46$ and $p = 0.00$ and $B = 0.30$, $SE = 0.05$, $\beta = 0.46$ and $p = 0.00$ for numeracy and vocabulary, respectively) and, therefore, it was imperative to control for this construct.

Discussion

This study aims to examine the relationship between numeracy and vocabulary skills of Indonesian preschool children and disentangle the effects of specific aspects of learning environments on both numeracy and vocabulary skills of young children.

The data confirmed hypothesis 1 about the significant relationship between numeracy and vocabulary skills with Pearson bivariate correlations yielded 0.57 and significant covariation in a structural equation model with $B = 0.12$, $SE = 0.26$, $\beta = 0.48$ and $p = 0.00$ (see Table 3). These results were in line with the reported results from various countries and settings that highlight the strong relationship between numeracy and vocabulary during early childhood (Duncan et al., 2007; Toll & Van Luit, 2014). Prior studies argued that numeracy and vocabulary skills mutually influence each other (Toll & Van Luit, 2014). Generally, vocabulary is a fundamental component of learning, and therefore, the acquisition of numeracy and mathematics and other domains of competencies is highly dependent on the acquisition of language (Duncan et al., 2007). More specifically, oral language skills seem to be an incredible predictor of a child's capabilities in completing more complex numeracy tasks (Duncan et al., 2007). A similar argument is also true for numeracy because components of thinking that are involved in numeracy, such as logical thinking, abstraction, and problem-solving, have a broad application to learning and, therefore, numeracy skills during early childhood do not only predict later numeracy skills but also later capabilities in literacy (Duncan et al., 2007). In addition, from the longitudinal perspectives, the mutual effects of numeracy and vocabulary seem to persist in the later development of children and this argument was empirically confirmed by the reports about strong connections between mathematics and both reading and language skills (Peng et al., 2020).

Interestingly, results indicated that home learning environments are not good predictors of numeracy, while preschool activities related to playful movement seem to explain the significant variance of this construct with $B = 0.23$, $SE = 0.10$, $\beta = 0.20$ and $p = 0.02$ (see Table 3), which partly confirmed hypothesis 2. The literature documented that bodily movements are associated with numeracy skills of preschool children and intervention studies found positive and long-term effects on numeracy performances (Jylänki et al., 2022). One possible explanation for this finding is the

fact that particularly complex motor tasks activate similar brain regions as complex cognitive tasks, and therefore, there is co-activation of the brain areas for cognitive function (i.e., cerebellum) during bodily movements (Diamond, 2000).

In general, children learn through playing (Coltman et al., 2006) and during playing all children's developmental aspects such as cognitive, social-emotional, language, literacy, physical, and spiritual are interrelated and interdependent (Epstein, 2007). Children can be perceived as active and engaged players because they play through active body movements and are not passive observers (Thompson & Goldstein, 2019). Unfortunately, due to various preschool learning activities that require sitting (Määttä et al., 2019), the likelihood of children being physically active, conducting body movements, and training their motor skills is often limited (Vanderloo et al., 2013). The result of a significant contribution of movement activities in preschool in determining numeracy skills suggests that movement activities are an important part of learning during preschool and shall be included in the daily learning activities. However, the data showed that some preschools conduct movement activities only once a week, which indicates that these preschools may not see movement activities as an important element of early childhood education. This condition may be an impact of health protocols following COVID-19 (see also challenges faced by preschools during COVID-19, which related to body movement: Lafave et al., 2021). Although social distancing rules were fully revoked in 2022, there are some health protocols that should be followed by Indonesian educational institutions such as using a mask indoors, which may be a challenge to do physical activities in the preschools. Nonetheless, given the results of this study, it is important for the children to do body movement activities on a daily basis.

Furthermore, the results also showed that home numeracy activities and not home literacy environments explain a significant amount of variance in vocabulary, which also partly confirmed hypothesis 3. Since the correlation between numeracy and vocabulary was relatively high (see Table 2), it is unsurprising that home numeracy activities can explain the significant variance in vocabulary. To add to the abovementioned explanation about the correlation between numeracy and vocabulary, prior studies have noted that numeracy is a stronger predictor of later reading than early literacy (Duncan et al., 2007) and certain mathematics curricula may affect both numeracy and language development (Sarama et al., 2012). Given the extensive reports that numeracy is related to and has predictive relevance to language, it is very likely that supportive home numeracy activities are positively associated with vocabulary skills. This result may be due to possibly high (and most likely more complex) language exposure children obtained on vocabulary during home numeracy activities (Napoli & Purpura, 2018).

It is possible that insignificant findings of home literacy environments were an impact of sample characteristics that predominantly have low socioeconomic status. (70% of parents had a senior high school certificate or lower.) SES has been documented as a main factor responsible for different facets in parenting behavior and quality parent–child interaction (Attig & Weinert, 2020). There are number of studies showed that home learning environments and parent–child interactions have a close link with education level of parents (Bradley et al., 2001; Neuhauser, 2018; Rowe, 2008) and that poverty is a significant contributor for the decreased quality of

interaction behavior and a decreased quantity and quality of language input (Hart & Risley, 1995; Rowe, 2008; Gudmunson, 2012).

Interestingly, the output of the structural equation model suggested that preschool literacy activities such as teacher–children joint reading, looking at picture books, singing, and dancing correlated negatively with vocabulary. The more literacy activities the children do in preschool, the less likely they have high vocabulary scores. This result seems to be counterintuitive and in contrast with research about the positive effect of informal literacy activities on the vocabulary of children (Novita & Kluczniok, 2022). One possible explanation for this surprising finding is that the teachers used both Indonesian and Sundanese during their interactions with the children. These language-mixing instructions that most teachers practice may affect the vocabulary of children in Indonesian due to possible competition input (Scheele et al., 2009) of both Indonesian and Sundanese. It was evident that in bilingual groups of English–Spanish children, activities that support English will contribute negatively to Spanish and vice versa (Quiroz et al., 2010). This competition model suggests that the language acquisition of bilingual children is not very similar to the language acquisition of monolingual children.

Sundanese is a local language within the Jatinangor district, and Indonesian is the official language in preschools. We did not consider that these languages are competing and providing a counterintuitive finding for this study. However, this is the most reasonable explanation for the results and may contribute to the improvement of the teaching instructions at the preschools in the Jatinangor district.

Conclusions and Limitations

This study examined the relationship between numeracy and vocabulary skills of Indonesian preschool children. It also wanted to disentangle the effects of home learning environments and preschool activities on both numeracy and vocabulary skills. The result highlighted the strong correlation between numeracy and vocabulary as two mutually important domains of competence. In addition, this study also found a significant relationship mostly between preschool activities and both numeracy and vocabulary skills as well as between home numeracy activities and vocabulary skills.

Although this study contributes to the information gap on Indonesian preschool children in both numeracy and vocabulary skills, it has several limitations. First, the sample size was not very big, which limits analysis possibilities using the structural equation model.

Second, we did not measure parent–child interactions in language and the frequency of teacher–children using Sundanese during their interactions with children. This may be one of the biggest shortcomings of this study, and therefore, the interpretations of the findings should be treated cautiously.

Third, we did not collect the data regarding years of teaching experiences of teachers, and therefore, it was not possible to use this important variable as a covariate in the model.

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