Exploring Peer Interaction in Collaborative Learning to Support Numeracy Skills among Early Childhood Learners

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Abstract

Collaborative learning has been recognised as an optimal pedagogical approach; its systematic application in early childhood numeracy education remains underexplored in Indonesia. This qualitative exploratory case study investigates how peer interaction within collaborative learning supports numeracy skill development among young learners, collecting data through systematic, non-participatory classroom observations guided by a structured rubric and the analysis of student group work artefacts across 11 collaborative numeracy activities in two early childhood education settings. Findings indicate that the quality of peer interaction significantly influences numeracy outcomes. Activities that promoted active participation, interdependence, mathematical dialogue, joint decision-making, and peer scaffolding led to a stronger understanding of key numeracy concepts, including one-to-one correspondence, cardinality, number sequencing, and early addition. Conversely, activities with minimal collaborative structure resulted in less optimal learning outcomes and limited mathematical discussion. The study demonstrates that young children are capable of meaningful collaboration when supported by intentionally designed instructional strategies. Peer interaction during numeracy tasks encourages the co-construction of knowledge, allowing children to externalise their thinking, negotiate meaning, and refine their mathematical understanding through verbal exchanges. Furthermore, the teachers role in structuring group activities, setting clear collaborative goals, and providing timely facilitation was instrumental in fostering an environment conducive to meaningful peer interaction. The study underscores the potential of collaborative learning structures to enhance both cognitive and social dimensions of early numeracy learning. It advocates the intentional integration of peer interaction opportunities into early childhood curricula to support the development of numeracy skills and deepen mathematical engagement.

Keywords: peer interaction, collaborative learning, early childhood education, numeracy development, classroom observation

Introduction

The early years of a child's life are foundational for cognitive, social, and emotional development, during which numeracy skills play a vital role. Numeracy in early childhood encompasses not only the understanding of numbers but also includes spatial awareness, pattern recognition, measurement, and early problem-solving abilities (Duncan et al., 2007; Parviainen et al., 2023). These skills are strong predictors of future success in mathematics and broader academic achievement (Seitz & Weinert, 2022). Recognising this, the Indonesian Merdeka curriculum has placed numeracy as a central element in early childhood education (Affrida & Kurniawan, 2023), encouraging educators to embed mathematical thinking in everyday activities.

One promising approach to strengthening early numeracy is collaborative learning, where children work together to explore concepts and solve problems. Collaborative settings offer rich opportunities for children to communicate, negotiate meanings, and build understanding through social interaction (Murphy et al., 2025). Particularly in numeracy learning, peer interaction allows children to verbalise their thinking, compare strategies, and learn from one another, fostering both cognitive and language development (Zippert et al., 2019). However, despite its potential, the effectiveness of collaborative learning depends largely on the quality of peer interaction. In many early childhood classrooms, children may engage in parallel play or off-task talk rather than productive mathematical dialogue.

Although collaborative learning has been widely promoted as a highly effective pedagogical strategy across various levels of education, its comprehensive implementation in early childhood numeracy remains very limited (Björklund et al., 2020; Deshaies, 2025). Numerous educators and researchers have analysed the feasibility and practicality of implementing effective collaborative learning approaches with young learners, citing developmental considerations and potential challenges in managing group dynamics (O'Donnell & Hmelo-Silver, 2013). This creates a significant gap between theoretical advocacy for collaborative learning in early childhood education and its actual practical implementation in Indonesian early childhood education settings. Furthermore, the lack of specific guidance and clear, robust evidence on collaborative numeracy learning in early childhood contexts hinders its wider adoption, leaving educators without the resources and clear frameworks needed to integrate the approach into their daily teaching practices effectively.

In the Indonesian context, research on peer interaction during collaborative numeracy activities in early numeracy learning remains limited. The nuances of how children explain ideas, ask questions, respond to peers, or co-construct solutions are often overlooked. This highlights a gap in understanding the interaction patterns that support or hinder learning in such settings. Furthermore, there is a need for evidence-based strategies to guide educators in facilitating effective peer interactions that truly enhance numeracy development in early childhood settings. This study, therefore, aims to explore peer interaction among early learners within collaborative learning to support numeracy skills, providing insights that can inform teaching practices and early childhood pedagogy.

Numeracy in Early Childhood Education

Numeracy in early childhood education refers to the development of young children's understanding of numbers, counting, patterns, measurement, and problem-solving, which provide the foundation for later mathematical learning (Clements & Sarama, 2014; Raghubar & Barnes, 2017). For example, an understanding of one-to-one correspondence is a key foundation for the development of childrens numeracy skills, as it ensures that each object counted is paired with a unique number and that each number corresponds to a specific object. Research has shown that this concept enables children to count objects in an organised and accurate way, supporting their ability to grasp more complex operations such as addition and subtraction (Clements & Sarama, 2010; Koopman et al., 2019). Closely related is the principle of cardinality, which highlights that the number of objects in a group remains the same even if their arrangement changes, reflecting children's growing ability to connect numbers with quantities (Pixner et al., 2018).

In addition, early numeracy involves quantity manipulation, particularly through non-symbolic activities such as comparing and grouping physical objects (Bernabini et al., 2020). Studies show that engaging in hands-on numeracy

tasks, such as sorting or arranging objects, strengthens children's understanding of concepts such as more, less, and the same, while also preparing them to comprehend later abstract symbolic mathematics (Aunio & Räsänen, 2016). Altogether, grounding early numeracy development in principles such as one-to-one correspondence, cardinality, and quantity manipulation underscores the importance of learning environments and teaching strategies that foster these skills, enabling children to build strong foundations for future mathematical understanding.

Collaborative Learning Approach

Collaborative learning is defined as an activity in which students work together in small groups to solve problems, complete tasks, or achieve goals, emphasising not uniformity of thought but the joint exploration, discovery, and comprehension of concepts through mutual activities (Lin, 2015; O'Donnell & Hmelo-Silver, 2013). Group work thus becomes a platform for uncovering both differences and shared understandings, and this study applies the concept to observe how early learners can engage in numeracy activities such as counting and sorting exercises within small groups, focusing not only on task completion but also on how group processes and interactions contribute to the development of numeracy skills.

Beyond academics, collaborative learning has also been shown to enhance social skills, as students develop interaction, collaboration, and conflict resolution abilities through interaction, learning to express themselves effectively, listen to others' opinions, and work together toward common goals (Laal & Laal, 2012). These interpersonal skills are vital not only in educational contexts but also in preparing students for professional environments that demand teamwork and cooperation, showing that collaborative learning simultaneously builds academic competence and equips students to function effectively in real-world collaborative settings (Dovigo, 2016; Lin, 2015).

Based on theoretical perspectives, this study integrates core early numeracy concepts as the theoretical foundation for examining numeracy skills through collaborative learning, examining how small-group interactions and shared activities support early learners' numeracy development in the early childhood education context.

Methodology

This research used a qualitative approach with an exploratory case study design to deeply explore the dynamics of peer interaction in collaborative numeracy learning in early childhood education. This approach was chosen because it captures complex phenomena in a natural context and provides a comprehensive understanding of participants experiences (Benaquisto & Given, 2008; Cresswell, 2013). The research was conducted in two schools, Mars School and Pluto School, focusing on classes A and B, which are in the early stages of numeracy development.

Teachers participating in the study were selected based on specific criteria: at least three years of early childhood teaching experience, a bachelors degree in early childhood education, and experience implementing collaborative numeracy learning. The case study design allowed researchers to examine learning practices in a real-life context and answer the questions "how" and "why" collaborative numeracy strategies are implemented in the classroom (Gillham, 2010; Lewis, 2015)

Data collection was conducted through two primary techniques: classroom observation and analysis of student work. Observations were conducted non-participatory using a structured rubric designed to capture key dimensions of students' engagement in collaborative numeracy learning, the rubric functioned as an observation instrument to systematically identify the parameter of how students works in collaborative numeracy learning settings, this instrument is important to see the features that shapes in the numeracy learning by focusing on eight core components such as (1) active participation, (2) sharing ideas and thinking, (3) attentive listening, (4) joint decision making, (5) collaborative problem solving, (6) giving and receiving feedback, (7) mutual support and assistance, and (8) group reflection. These indicators guided the observer in systematically documenting the quality and patterns of collaboration, which subsequently informed the interpretation of the research findings.

Data validity was strengthened by involving two doctoral students as external observers and applying inter-observer reliability testing. Inter-observer reliability in this study refers to the consistency of observational judgments among multiple observers when assessing children's collaborative behaviours during numeracy learning activities. This concept is important to ensure that a single observers subjective interpretation does not influence the findings. In this research, inter-observer reliability was established by involving two external observers who independently examined the same classroom interactions using the structured rubric. After each observation session, the observers compared and discussed their recorded findings to resolve any differences in interpretation. (Johnson & Christensen, 2020). Analysis of student work was used to assess the extent to which collaborative activities contributed to understanding of numeracy concepts, in line with constructivist theory, which emphasises students active role in constructing knowledg e (Bada & Olusegun, 2015). Furthermore, a research instrument was developed by synthesising key elements of collaborative learning and early numeracy skills to obtain a comprehensive picture of the observed learning processes and outcomes. This synthesis involved identifying, integrating, and summarising core elements derived from multiple scholarly sources. These elements were selected for their relevance and recurring emphasis in the literature and consolidated into a set of operational indicators used during data collection.

Results and Discussions

This study reveals that collaborative learning has great potential to strengthen numeracy skills and understanding among early childhood students. Throughout the data collection process, 11 collaborative numeracy learning activities were documented in Table 1. The table illustrates different hands-on, play-based activities tailored to each class level at the two schools, highlighting the integration of manipulatives and collaborative tasks to support students' development of numeracy skills.

Table 1

List of students' collaborative numeracy activities

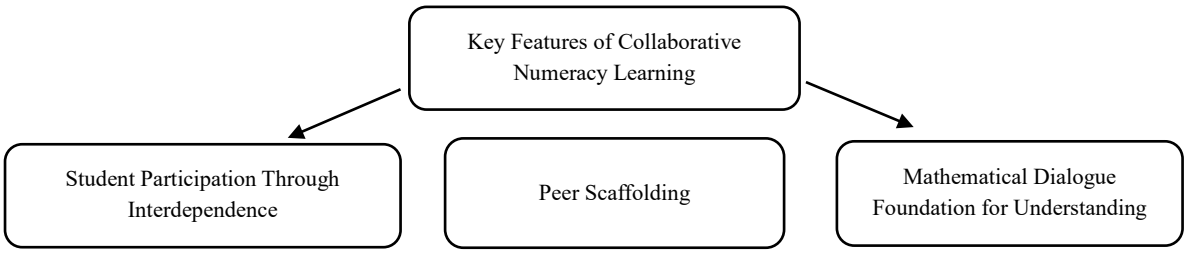
School	Class	Activities
School Mars	Class A	1. Pyramid construction according to the number order 2. Arranging a number puzzle 3. Pasting college materials onto numbers
	Class B	4. Found number cards 5. Identifying missing numbers 6. Counting bottle caps

School	Class	Activities
School Pluto	Class A	7. Arranging LEGO with number blocks 8. Building a store with blocks.
	Class B	9. Sorting numbers (1 to 20) using bottle caps 10. Building structure using wooden blocks 11. Counting the ball

The findings of this study underscore collaborative numeracy learning structures in early childhood that can shape meaningful learning interactions, especially through student participation, interdependence, peer scaffolding, and mathematical dialogue, which serve as a foundation for understanding numeracy skills. The collaborative learning activities were analysed to identify the key features that support students' numeracy skills, as illustrated in Figure 1.

Figure 1

Key Features of Collaborative Learning Supporting Numeracy Skills



Furthermore, the results of the study indicate that strong collaboration enhances the positive effects of numeracy learning, as illustrated in Figure 2, whereas low collaboration hinders students numeracy achievement (see Figure 3). First, the findings show that collaboration supports numeracy learning, for example, through group activities such as arranging pyramids. During the pyramid construction activity, all students were actively involved in sharing ideas, making decisions together, checking for accuracy, and reflecting on results to complete the task collaboratively, thereby promoting number ordering.

The pyramid construction activity shows the achievement of two important numeracy indicators in early childhood education. First, children demonstrate an understanding of one-to-one correspondence by matching each numbered bottle to its position in the pyramid. This illustrates the childs ability to correctly associate a concrete object with a specific number, as stipulated in the Indonesian ECE Standards and Curriculum. Second, they understand the number symbols from 1 to 6 and can sequence them logically, which aligns with the counting indicators outlined by ACARA (Australian Curriculum, Assessment and Reporting Authority). Although still in the early stages of numeracy development, children can recognise, differentiate, and arrange numbers with minimal teacher guidance and through active interaction with their group members. Thus, constructing a Pyramid is an effective activity for integrating numeracy and collaborative learning in class A.

The use of real objects directly develops students understanding of one -to-one correspondence, namely the ability to match each object with one number, which is the foundation of numeracy skills. The teacher then adds several bottle caps to the pair without mentioning the exact number and asks students to discuss the total number again (see figure 2). This process not only encourages children to use basic addition strategies but also strengthens mathematical communication skills, such as making guesses, comparing answers, and verifying together. This interaction leads to the

meaningful, concrete application of the concept of addition in everyday contexts. This stage directly supports the numeracy indicators set by ACARA, namely “Solve everyday addition and share stories”.

Figure 2

Strong collaboration activities supporting numeracy learning

Lastly, the other two activities, Arranging LEGO According to Number Sequence, are categorised as less collaborative numeracy activities. This activity shows minimal social interaction among students, a predominance of individual approaches, and a lack of a clear group-work structure. Although this activity has the potential to develop numeracy skills, such as recognising numbers and number sequences, the learning outcomes are not optimal due to a lack of collaborative support during the process. The lack of peer involvement and teacher facilitation in encouraging collaboration caused some students to have difficulty completing numerical tasks effectively.

Figure 3

The result of the students work

Figure 3 above illustrates the result of the students work; the number order does not follow the sequence number. Based on the analysis of the 11 activities in group-based numeracy learning, it can be concluded that the quality of collaborative interaction may influence the achievement of early childhood numeracy skills. Two activities, namely constructing a pyramid and counting and adding bottle caps, show the characteristics of strong collaborative numeracy activities that can help strengthen students’ understanding in figuring out the numeracy tasks, where interaction between students takes place actively, joint decision-making occurs, and the use of concrete media plays a role in building meaningful numerical

understanding. These activities not only support the achievement of numeracy indicators such as one-to-one correspondence and counting, but also facilitate collaborative skills such as peer interactions, discussion, and mutual support between group members.

Conclusion and Implications

This research shows that key elements of collaborative learning, namely, students participation through interdependence, mathematical dialogue, and peer scaffolding, have great potential to strengthen early childhood numeracy skill development. When implemented effectively, these strategies create a learning environment that encourages active participation, the exchange of ideas, and the building of shared understanding. Conversely, minimal collaboration in groups often led to non-optimal numeracy skills outcomes.

These findings have important implications for early childhood education practices, particularly in Indonesia. This research challenges the assumption that young children are not yet capable of meaningful collaboration, especially in the context of numeracy learning. Teachers and curriculum developers need to begin integrating consciously designed collaborative strategies that can strengthen the process of early childhood students' conceptual understanding and enhance their capacity to engage in and resolve numeracy-related problems they encounter, such as forming heterogeneous groups, assigning tasks that encourage collaborative problem-solving, and explicit peer scaffolding to strengthen group dynamics. However, this study is limited in participant coverage and perspective, as it involved only two schools. Therefore, further research is recommended that encompasses more diverse contexts and utilises longitudinal methods to deepen understanding of collaborative dynamics in supporting numeracy learning to strengthen the numeracy skills of early childhood students. This approach is expected to enrich the practice and development of collaborative numeracy learning in the future.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

In writing this manuscript, I used generative and AI-assisted technologies to support the writing process. Specifically, I used Gemini AI to help identify relevant and reputable academic sources for the literature review and introduction sections. Furthermore, I used AI tools to help improve the structure and clarity of the English in this manuscript, as English is not my first language. These technologies were used solely for language improvement and source retrieval; all critical thinking, analysis, and interpretation were done independently by the author.

References

Affrida, E. N., & Kurniawan, A. (2023). Pelatihan pengembangan kegiatan numerasi berbasis Merdeka Belajar Merdeka Bermain pada guru di satuan pendidikan anak usia dini. *Jurnal Gembira: Pengabdian Kepada Masyarakat*, *1*(03), 691-696.

Aunio, P., & Räsänen, P. (2016). Core numerical skills for learning mathematics in children aged five to eight years – a working model for educators. *European Early Childhood Education Research Journal, 24*(5), 684–704. https://doi.org/10.1080/1350293X.2014.996424

Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education, 5*(6), 66–70.

Benaquisto, L., & Given, L. (2008). The SAGE encyclopedia of qualitative research methods. *Given L, ed*, *413*.. https://edge.sagepub.com/system/files/Ch10CodesandCoding.pdf

Bernabini, L., Tobia, V., Guarini, A., & Bonifacci, P. (2020). Predictors of Children's Early Numeracy: Environmental Variables, Intergenerational Pathways, and Children's Cognitive, Linguistic, and Non-symbolic Number Skills. *Frontiers in Psychology, 11,* 505065. https://doi.org/10.3389/fpsyg.2020.505065

Björklund, C., Van Den Heuvel-Panhuizen, M., & Kullberg, A. (2020). Research on early childhood mathematics teaching and learning. *ZDM, 52*(4), 607–619. https://doi.org/10.1007/s11858-020-01177-3

Clements, D. H., & Sarama, J. (2009). Learning trajectories in early mathematics–sequences of acquisition and teaching. *Encyclopedia of language and literacy development*, *7*, 1-6.

Clements, D. H., & Sarama, J. (2020). *Learning and teaching early math: The learning trajectories approach*. Routledge.

Cresswell, J. (2013). *Qualitative inquiry & research design: Choosing among five approaches.* https://repositorio.ciem.ucr.ac.cr/jspui/bitstream/123456789/501/1/Qualitative%20inquiry%20&%20research%20design.%20design%20_%20Choosing%20among%20five%20approaches.%20(1).pdf

Deshaies, I. (2025). Changes in Support Intervention Practices in Mathematics for 5-Year-Old Preschool Education: The Importance of a Collaborative and Reflective Process. *Education Sciences, 15*(6), 741. https://doi.org/10.3390/educsci15060741

Dovigo, F. (2016). Argumentation in preschool: A common ground for collaborative learning in early childhood. *European Early Childhood Education Research Journal, 24*(6), 818–840. https://doi.org/10.1080/1350293X.2016.1239327

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

Gillham, B. (2010). Case study research methods. https://www.torrossa.com/it/resources/an/5202034

Johnson, R. B., & Christensen, L. B. (2024). *Educational research: Quantitative, qualitative, and mixed approaches*. Sage publications.

Koopman, S. E., Arre, A. M., Piantadosi, S. T., & Cantlon, J. F. (2019). One-to-one correspondence without language. *Royal Society Open Science, 6*(10), 190495. https://doi.org/10.1098/rsos.190495

Laal, M., & Laal, M. (2012). Collaborative learning: what is it?. *Procedia-Social and Behavioral Sciences*, *31*, 491-495. https://doi.org/10.1016/j.sbspro.2011.12.092

Lewis, S. (2015). Qualitative Inquiry and Research Design: Choosing Among Five Approaches. *Health Promotion Practice, 16*(4), 473–475. https://doi.org/10.1177/1524839915580941

Lin, L. (2015). Exploring Collaborative Learning: Theoretical and Conceptual Perspectives. In L. Lin, *Investigating Chinese HE EFL Classrooms* (pp. 11–28). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-44503-7_2

Murphy, C., Muir, T., & Thomas, D. (2025). Scaffolding Collaboration in Early Years Mathematics: A Practice-Based Case Study in Teaching Multiplicative Grouping. *Early Childhood Education Journal*, *53*(8), 3207-3217. https://doi.org/10.1007/s10643-025-01928-5

O'Donnell, A. M., & Hmelo-Silver, C. E. (2013). Introduction: What is collaborative learning?: An overview. *The international handbook of collaborative learning*, 1-15.

Parviainen, P., Eklund, K., Koivula, M., Liinamaa, T., & Rutanen, N. (2023). Teaching early mathematical skills to 3-to 7-year-old children—Differences related to mathematical skill category, children's age group and teachers' characteristics. *International journal of science and mathematics education*, *21*(7), 1961-1983. https://doi.org/10.1007/s10763-022-10341-y

Pixner, S., Dresen, V., & Moeller, K. (2018). Differential development of children's understanding of the cardinality of small numbers and zero. *Frontiers in Psychology*, *9*, 1636. https://doi.org/10.3389/fpsyg.2018.01636

Raghubar, K. P., & Barnes, M. A. (2017). Early numeracy skills in preschool-aged children: A review of neurocognitive findings and implications for assessment and intervention. *The Clinical Neuropsychologist, 31*(2), 329–351. https://doi.org/10.1080/13854046.2016.1259387

Seitz, M., & Weinert, S. (2022). Numeracy skills in young children as predictors of mathematical competence. *British Journal of Developmental Psychology, 40*(2), 224–241. https://doi.org/10.1111/bjdp.12408

Zippert, E. L., Eason, S. H., Marshall, S., & Ramani, G. B. (2019). Preschool children's math exploration during play with peers. *Journal of Applied Developmental Psychology, 65,* 101072. https://doi.org/10.1016/j.appdev.2019.101072

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