

Rethinking Mediation in Early Childhood Mathematics: A Conceptual Framework Informed by Inclusive Research [†]

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Abstract

This paper starts from an understanding of intelligence as learning potential that develops through mediated participation in social, material, and cultural practices. The study examines how mediation is conceptualized in early childhood mathematics education through an integrative literature review of 23 studies across mathematics education and related fields. While semiotic mediation provides a strong theoretical foundation for understanding the role of artefacts, signs, and teacher-guided interaction, the analysis highlights embodied, multimodal, environmental, and relational aspects that often remain implicit in research and practice. Informed by inclusive research, the study offers a conceptual framework for making these aspects more visible. The paper contributes to a more fine-grained understanding of mediation, with implications for inclusive approaches to early childhood mathematics education.

Keywords: mediation; early childhood mathematics education; inclusive research

1. Introduction

This paper starts from an understanding of intelligence as learning potential that develops through mediated participation in social, material, and cultural practices [1–4]. This view is consistent with perspectives on cognitive modifiability, which emphasize that learning potential is not fixed, but can be supported through the quality of mediation provided in interaction [5,6]. From this perspective, mediation is central to discussions of human intelligence because it helps explain how children’s cognitive development is shaped through interaction with others, artefacts, communication channels, and learning environments.

This understanding is particularly relevant in early childhood mathematics education. Mathematics is often experienced as exclusionary, especially for learners with diverse ways of thinking and communicating [7]. If mathematical learning is understood as something that develops through participation, interaction, and mediation, then attention must be directed not only to what children learn, but also to how teachers, artefacts, environments, and forms of communication support children’s access to mathematical meaning. Within mathematics education, the framework of semiotic mediation has provided a powerful lens for analyzing how artefacts and signs support the development of mathematical meaning through teacher-guided processes [8,9]. Recent studies in early childhood mathematics further show that mediation is closely connected to teacher responsiveness, scaffolding, play-responsive teaching, and embodied forms of mathematical meaning-making [10–12].



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At the same time, research on mediation has developed across multiple theoretical traditions, including embodied cognition, multimodal learning, environmental perspectives, and inclusive research, which are often treated separately. Research in mathematics education has increasingly highlighted the role of bodily action, multiple modes of communication, and structured learning environments in supporting mathematical understanding. Studies have shown that gestures contribute to the development of mathematical ideas [13], that teachers communicate mathematical relations through coordinated multimodal resources such as speech and gesture [14], and that learning environments shape the quality of mathematical engagement [15,16]. Furthermore, research in embodied cognition demonstrates that mathematical thinking emerges from the dynamic interaction between perception and action [17], while studies in early childhood education confirm the importance of embodied modes for young children's mathematical learning [10]. Research also indicates that mathematical understanding is not limited to visual representations, but can be constructed through tactile and auditory modalities, highlighting the inherently multimodal and embodied nature of mathematical cognition [18].

As a result, there is currently a fragmented understanding of mediation in early childhood mathematics education, where key dimensions of learning processes are not fully integrated within existing frameworks.

To address this fragmentation, this study does not aim to extend the framework of semiotic mediation by introducing new components. Rather, it aims to make visible and articulate dimensions of mediation that are already present in educational practice but are not always explicitly theorized.

This perspective is informed by inclusive research [19,20], which foregrounds diverse forms of participation and communication and enables a more fine-grained understanding of how mediation unfolds in practice.

2. Semiotic Mediation as a Foundational Framework

The framework of semiotic mediation [8,9] provides a well-established theoretical foundation for understanding how mathematical knowledge develops through interaction with artefacts and guided activity. Within this perspective, learning is conceptualized as a mediated process in which artefacts, signs, and social interaction play a central role in the construction of mathematical meaning.

A key assumption of this framework is that artefacts are not neutral tools but are intentionally designed and selected to support mathematical activity. Through engagement with artefacts, learners participate in situated actions that give rise to mathematical meanings. These meanings are not directly embedded in the artefacts themselves, but emerge through the interaction between learners, artefacts, and the teacher.

Central to semiotic mediation is the role of semiotic processes in transforming situated activity into shared mathematical knowledge. Through guided interaction, learners progressively move from context-bound actions and personal meanings towards the use of mathematical signs and culturally established representations. This process involves production, negotiation, and refinement of signs, linking concrete activity to more formal mathematical understanding.

The teacher plays a crucial role in orchestrating this process of mediation. Through intentional guidance, questioning, and the organization of activity, the teacher supports the emergence of mathematical meanings and facilitates the transition from informal exploration to more structured forms of mathematical reasoning.

While semiotic mediation provides a powerful framework for understanding how artefacts and signs support mathematical learning, it primarily focuses on symbolic processes and teacher-guided interaction. As a result, other dimensions of learning—such as

bodily engagement, multimodal communication, and the role of the environment—are less explicitly theorized within this framework.

Figure 1 illustrates the core elements of the semiotic mediation framework.

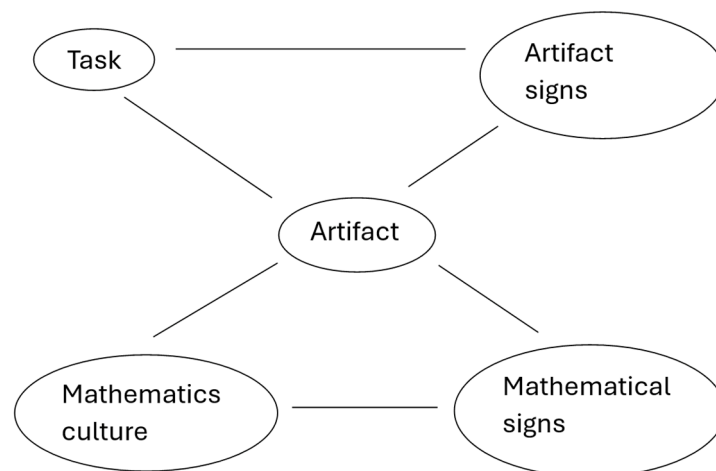


Figure 1. Semiotic mediation model adapted from Bartolini Bussi & Mariotti [8].

3. Method

This study adopts an integrative literature review approach [21] to explore how mediation is conceptualized in early childhood mathematics education and across related research traditions. This approach allows for the inclusion and synthesis of both empirical and theoretical studies from different fields in order to develop a comprehensive and multidimensional understanding of mediation.

The analysis was focused specifically on studies addressing mediation in mathematics education within early childhood education.

The framework of semiotic mediation [8,9] was used as a theoretical starting point, with its focus on artefacts, signs, and teacher-guided processes in supporting the development of mathematical understanding.

A set of analytical questions guided both the literature search and the analysis. These questions addressed how mediation is conceptualized, which dimensions of mediation are emphasized, and how learning is supported across different contexts.

Literature searches were conducted using major academic databases, namely Scopus (Elsevier B.V., Amsterdam, The Netherlands), Web of Science (Clarivate, Philadelphia, PA, USA), and ERIC (Institute of Education Sciences, U.S. Department of Education, Washington, DC, USA). Searches combined keywords related to mediation, mathematics education, early childhood education, embodiment, multimodality, and learning environments. The screening, comparison, and thematic synthesis were conducted manually; no qualitative data analysis software was used.

Inclusion criteria were defined focusing on studies that explicitly addressed mediation processes, were directly related to mathematics learning, were situated within early childhood education, provided empirical or theoretical insights into how mediation supports the development of mathematical understanding.

Studies that did not explicitly address mediation processes in relation to mathematics learning in early childhood education were not included in the analytical sample.

The selected studies were analyzed qualitatively using an iterative comparative approach informed by principles of thematic analysis [22]. Each study was examined in relation to how mediation was conceptualized and enacted, with particular attention to the role of artefacts and signs, bodily engagement and action, modes of communication, environmental and organizational conditions, forms of participation.

Through iterative comparison across studies and strands, recurring patterns were identified and synthesized into a set of dimensions of mediation.

Inclusive research informed the analytical perspective of this review. The study itself was conducted as an integrative literature review, rather than as a participatory empirical study. However, the analytical framework used to interpret the literature was developed through previous inclusive research conducted by the author in collaboration with co-researchers with intellectual and developmental disabilities [19,20,23]. This is consistent with recent work in disability studies, which emphasizes the importance of active involvement, power sharing, and attention to the conditions that enable meaningful collaboration in participatory research [24]. In this sense, inclusive research was not treated as an additional theme to be identified in the literature, but as a lens for attending to forms of participation, communication, and interaction that may remain less visible in more conventional analyses. This perspective guided the interpretation of how mediation was described across the selected studies, particularly in relation to embodied engagement, multimodal communication, environmental conditions, and relational participation.

The results of this analysis are presented in the following section.

4. Results and Discussion

The analysis included 23 studies examining mediation in early childhood mathematics education and related research traditions. Table 1 presents an overview of the selected studies, including their focus, and contribution to different dimensions of mediation. For each study, the analysis identified two elements: the main dimension(s) of mediation addressed and the specific focus through which mediation was discussed. The term “focus” in Table 1 refers to the primary analytical emphasis of each study, such as gesture, teacher support, mathematical representations, learning environments, or participation. These focuses were not predefined categories but were assigned through iterative reading and comparison of the selected studies. The dimensions of mediation were then synthesized across studies in order to identify broader patterns in how mediation is conceptualized in early childhood mathematics education and related research traditions.

Table 1. Overview of selected studies on mediation in early childhood mathematics education and related research traditions.

Article	Focus	Dimension(s) of Mediation
[25]	Gesture and learning	Embodied, multimodal
[14]	Gesture in instruction	Embodied, multimodal
[26]	Teacher support and representation	Semiotic, relational
[27]	Support for diverse learners	Inclusive
[28]	Participation in learning	Relational
[29]	Early mathematical interaction	Relational, semiotic
[15]	Early mathematics learning	Environmental
[30]	Spatial-numerical processing	Embodied
[31]	Mathematical exploration	Semiotic, relational
[19]	Inclusive research	Inclusive, multimodal, relational
[32]	Embodied interaction	Embodied, multimodal
[13]	Gesture in cognition	Embodied, multimodal
[33]	Numerical cognition	Embodied
[34]	Conceptual understanding	Semiotic
[35]	Learning environment design	Environmental
[36]	Mathematical representations	Multimodal
[11]	Classroom interaction	Relational

Table 1. *Cont.*

Article	Focus	Dimension(s) of Mediation
[37]	Learning trajectories and environments	Environmental
[18]	Multimodal representation	Multimodal
[38]	Early number understanding	Semiotic
[17]	Embodied cognition	Embodied
[10]	Embodied learning	Embodied
[16]	Classroom environment	Environmental

4.1. From Literature to a Multidimensional Understanding of Mediation

The results reported in Table 1 provide an interpretive mapping of the selected studies rather than a classification into mutually exclusive categories. The focus column identifies the main analytical emphasis through which mediation is addressed in each study, while the dimension column indicates the broader aspect of mediation to which this focus contributes. The table therefore shows how diverse research traditions foreground different, but often overlapping, aspects of mediation in early childhood mathematics education and related fields.

Three main patterns emerge from the analysis. First, several studies conceptualize mediation primarily through teacher-guided interaction, artefacts, and mathematical representations [31,34,38]. These studies are closely aligned with the framework of semiotic mediation [8,9], where the teacher supports the movement from situated activity towards shared mathematical meanings. In this strand, mediation is mainly understood as a process through which children's actions, signs, and representations are guided and progressively connected to mathematical concepts.

Second, a substantial group of studies foregrounds embodied and multimodal aspects of mediation. These studies show that mathematical meaning is not constructed only through verbal explanation or symbolic representation, but also through gesture, bodily action, spatial positioning, tactile engagement, visual representations, and interaction with artefacts [10,13,14,17,18,25,30,33]. From this perspective, mediation involves the coordination of multiple modes of meaning-making. This is particularly relevant in early childhood education, where children often express mathematical understanding through action, movement, manipulation, and non-verbal forms of communication.

Third, the analysis shows that mediation is shaped by relational and environmental conditions. Several studies emphasize participation, joint attention, interaction, and teacher responsiveness as central to mathematical learning [11,28,29,31]. Other studies point to the importance of the organization of the learning environment, including the availability of materials, spatial arrangements, and the structure of activities [15,16,37]. These studies suggest that mediation does not occur only through direct teacher explanation, but also through the ways in which environments, materials, and social relations make participation possible.

The studies therefore indicate that mediation in early childhood mathematics education is not a single or linear process. Rather, it emerges through the interaction of semiotic, embodied, multimodal, environmental, and relational aspects. These aspects are analytically distinguishable, but they are intertwined in practice. For example, a gesture may function simultaneously as an embodied action, a communicative mode, and a semiotic resource; similarly, an artefact may support mathematical meaning only when it is embedded in a responsive interaction and an organized learning environment.

An inclusive research perspective helps to make these interconnections more visible. By foregrounding diverse ways of participating and communicating [19,20], this perspective draws attention to aspects of mediation that may remain implicit if learning is analyzed

mainly through verbal explanation or symbolic representation. The analysis therefore does not suggest that new components should simply be added to semiotic mediation. Rather, it shows the need for a more fine-grained reading of how mediation operates in practice, especially when the aim is to support inclusive mathematical learning in early childhood education.

Section 4.1 has therefore identified the main patterns emerging from the reviewed literature. The next section builds on these patterns to articulate how they can be organized into a conceptual framework for analyzing mediation in early childhood mathematics.

4.2. *A Conceptual Framework for a More Fine-Grained Reading of Mediation*

While the previous section identified recurring patterns across the reviewed studies, this section moves from synthesis to conceptualization. It proposes a framework for understanding how these patterns can be read together as interconnected aspects of mediation in early childhood mathematics education.

Building on the analysis presented above, this section proposes a conceptual framework for reading mediation in early childhood mathematics education in a more fine-grained way. The framework does not replace the framework of semiotic mediation, nor does it aim to introduce a separate theory of mediation. Rather, it builds on semiotic mediation as a foundational perspective and makes visible aspects of mediation that are already present in educational practice, but that may remain less explicit when attention is directed mainly towards artefacts, signs, and teacher-guided semiotic processes [8,9].

The need for such a framework emerges from the literature reviewed in this study and from recent research in early childhood mathematics education. Studies have shown that mathematical learning is shaped not only through symbolic representations, but also through embodied engagement, multimodal communication, teacher responsiveness, scaffolding, play-responsive teaching, and the organization of learning environments [10–12,26,36]. These contributions suggest that mediation should be understood as a situated and dynamic process, in which mathematical meaning is constructed through the coordination of several interconnected aspects.

In this framework, artefacts remain central to mathematical mediation. However, they are not understood only as carriers of signs or as tools for producing mathematical representations. They are also points of interaction through which children act, move, communicate, negotiate meaning, and participate. An artefact may therefore mediate mathematical understanding through its semiotic potential, but also through the ways in which it invites bodily action, supports dialogue, enables visual or tactile exploration, and becomes embedded in the learning environment.

The role of the teacher is also understood as dynamic and responsive. In semiotic mediation, the teacher guides the movement from situated activity towards shared mathematical knowledge [8,9]. The proposed framework makes visible how this guidance depends on relational and adaptive processes, including attention to children's verbal and non-verbal contributions, responsiveness to their strategies, and the ability to reorganize mediation during the activity. In this sense, mediation is not only planned in advance but continuously adjusted in response to children's participation.

The learning environment is included as an integral component of mediation. Spatial arrangements, the availability and accessibility of materials, the organization of time, and the structure of the activity influence how children engage with mathematical ideas. The environment does not mediate learning independently of the teacher or the artefact, but shapes the conditions under which interaction, participation, and meaning-making become possible.

Communication is likewise understood as multimodal. Mathematical meaning may be expressed and negotiated through speech, gesture, bodily movement, visual representations, tactile exploration, and interaction with artefacts. This is particularly important in early childhood education, where children often communicate emerging mathematical understanding through action and embodied participation before, or alongside, verbal explanation.

A central feature of the framework is therefore the cyclical and adaptive nature of mediation. The teacher organizes mathematical activity through artefacts, environments, and communication channels, while children's responses provide continuous feedback that informs subsequent mediation. These responses may be explicit, such as verbal explanations or questions, or implicit, such as gesture, hesitation, movement, attention, or ways of engaging with materials. Through this cycle, mediation becomes a responsive process in which teaching and learning continuously shape each other.

Viewed through an inclusive research perspective, this framework supports attention to diverse forms of participation and communication [19,20,23]. It helps identify aspects of mediation that may remain unnoticed if learning is analyzed mainly through verbal or symbolic expression. The framework therefore contributes to a more inclusive understanding of early childhood mathematics education by showing how semiotic, embodied, multimodal, environmental, and relational aspects of mediation operate together in practice.

5. Conclusions

This study explored how mediation is conceptualized in early childhood mathematics education by synthesizing insights from mathematics education and related research traditions. The findings contribute to discussions of intelligence understood as learning potential, by showing how children's mathematical thinking and participation may be supported through mediated interaction with teachers, artefacts, communication channels, and learning environments.

While the framework of semiotic mediation provides a strong theoretical foundation, the reviewed literature suggests that mediation in early childhood mathematics education cannot be fully understood through artefacts, signs, and teacher-guided semiotic processes alone. The analysis points to embodied, multimodal, environmental, and relational aspects that are often implicit but play an important role in how mathematical meaning is constructed in practice.

The contribution of this study lies in proposing a conceptual framework for making these aspects more visible. Informed by inclusive research, the framework supports a more fine-grained reading of mediation by drawing attention to diverse forms of participation and communication. This is particularly relevant in early childhood education, where children may express mathematical understanding through movement, gesture, manipulation of materials, visual or tactile exploration, and interaction with others.

From this perspective, mediation is not only a strategy for supporting mathematical learning, but also a way of creating conditions in which children's learning potential can become visible and develop. Future empirical research is needed to investigate how these aspects of mediation unfold in practice, particularly in activities involving young children, teachers, artefacts, and diverse communicative resources.

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References

1. Edwards, S. Constructivism does not only happen in the individual: Sociocultural theory and early childhood education. *Early Child Dev. Care* **2005**, *175*, 37–47. [[CrossRef](#)]
2. Rubtsov, V.V. Two approaches to the problem of development in the context of social interactions: L.S. Vygotsky vs J. Piaget. *Cult.-Hist. Psychol.* **2020**, *16*, 5–14. [[CrossRef](#)]
3. Vygotsky, L.S.; Cole, M. *Mind in Society: Development of Higher Psychological Processes*; Harvard University Press: Cambridge, MA, USA, 1978.
4. Hutchins, E. *Cognition in the Wild*; MIT Press: Cambridge, MA, USA, 1995.
5. Feuerstein, R.; Hoffman, M.B.; Rand, Y.; Jensen, M.R.; Tzuriel, D.; Hoffmann, D.B. Learning to Learn: Mediated Learning Experiences and Instrumental Enrichment. *Spec. Serv. Sch.* **1985**, *3*, 49–82. [[CrossRef](#)]
6. Tzuriel, D. *Mediated Learning and Cognitive Modifiability*; Springer: New York, NY, USA, 2021.
7. Boaler, J. *Mathematical Mindsets: Unleashing Students' Potential Through Creative Mathematics, Inspiring Messages and Innovative Teaching*; John Wiley & Sons: Hoboken, NJ, USA, 2022.
8. Bartolini Bussi, M.G.; Mariotti, M.A. Semiotic mediation in the mathematics classroom: Artefacts and signs after a Vygotskian perspective. In *Handbook of International Research in Mathematics Education*, 2nd ed.; English, L.D., Ed.; Routledge: Oxfordshire, UK, 2008; pp. 746–783.
9. Bartolini Bussi, M.G.; Baccaglini-Frank, A. Geometry in early years: Sowing seeds for a mathematical definition of squares and rectangles. *ZDM Math. Educ.* **2014**, *47*, 391–405. [[CrossRef](#)]
10. Way, J.; Ginns, P. Embodied learning in early mathematics education: Translating research into principles to inform teaching. *Educ. Sci.* **2024**, *14*, 696. [[CrossRef](#)]
11. Murphy, C.; Muir, T.; Thomas, D. Scaffolding collaboration in early years mathematics: A practice-based case study in teaching multiplicative grouping. *Early Child. Educ. J.* **2025**, *53*, 3207–3217. [[CrossRef](#)]
12. Karlsson, L.; Palmér, H.; Carlsen, M. Quality of preschool teachers' mediation of early years mathematics in play-responsive teaching activities. *Educ. Stud. Math.* **2026**, *122*, 251–270. [[CrossRef](#)]
13. Goldin-Meadow, S.; Cook, S.W.; Mitchell, Z.A. Gesturing gives children new ideas about math. *Psychol. Sci.* **2009**, *20*, 267–272. [[CrossRef](#)] [[PubMed](#)]
14. Alibali, M.W.; Nathan, M.J.; Wolfram, M.S.; Church, R.B.; Jacobs, S.A.; Johnson Martinez, C.; Knuth, E.J. How teachers link ideas in mathematics instruction using speech and gesture: A corpus analysis. *Cogn. Instr.* **2014**, *32*, 65–100. [[CrossRef](#)]
15. Clements, D.H.; Sarama, J. Experimental evaluation of the effects of a research-based preschool mathematics curriculum. *Am. Educ. Res. J.* **2008**, *45*, 443–494. [[CrossRef](#)]
16. Weiss, I.; Kramarski, B.; Talis, S. Effects of multimedia environments on kindergarten children's mathematical achievements and style of learning. *Educ. Media Int.* **2006**, *43*, 3–17. [[CrossRef](#)]
17. Tran, C.; Smith, B.; Buschkuehl, M. Support of mathematical thinking through embodied cognition: Nondigital and digital approaches. *Cogn. Res. Princ. Implic.* **2017**, *2*, 16. [[CrossRef](#)] [[PubMed](#)]
18. Sedaghatjou, M. Advanced mathematics communication beyond modality of sight. *Int. J. Math. Educ. Sci. Technol.* **2018**, *49*, 46–65.
19. Bigby, C.; Frawley, P.; Ramcharan, P. Conceptualizing inclusive research with people with intellectual disability. *J. Appl. Res. Intellect. Disabil.* **2014**, *27*, 3–12. [[CrossRef](#)] [[PubMed](#)]
20. Strnadová, I.; Walmsley, J.; Johnson, K.; Cumming, T.M. Diverse faces of inclusive research: Reflecting on three research studies. *Scand. J. Disabil. Res.* **2016**, *18*, 52–64. [[CrossRef](#)]
21. Whittemore, R.; Knafl, K. The integrative review: Updated methodology. *J. Adv. Nurs.* **2005**, *52*, 546–553. [[CrossRef](#)] [[PubMed](#)]
22. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [[CrossRef](#)]
23. Granone, F. *Å Forstå Matematikk I Hverdagen*; Kolofon Forlaget: Oslo, Norway, 2026.
24. Corcuff, M.; Jribi, R.; Rodrigue, G.; Lamontagne, M.E.; Raymond, É.; Archambault, P.S.; Routhier, F. A mapping review of good practices of participatory research for an impactful collaboration in disabilities studies. *Disabil. Rehabil.* **2026**, *48*, 1845–1859. [[CrossRef](#)] [[PubMed](#)]
25. Alibali, M.W.; Nathan, M.J. Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *J. Learn. Sci.* **2012**, *21*, 247–286. [[CrossRef](#)]

26. Besser, N.; Linberg, A.; Dornheim, D.; Weinert, S.; Roßbach, H.-G.; Lehl, S. Fostering toddlers' numeracy and mathematical language skills through a professional development intervention on interaction quality in toddler classrooms. *Early Child. Res. Q.* **2025**, *72*, 44–55. [[CrossRef](#)]
27. Bouck, E.C.; Park, J. A systematic review of the literature on mathematics manipulatives to support students with disabilities. *Educ. Treat. Child.* **2018**, *41*, 65–106. [[CrossRef](#)]
28. Breive, S. Engaging children in mathematical discourse: A kindergarten teacher's multimodal participation. *NOMAD Nord. Stud. Math. Educ.* **2019**, *24*, 5–24. [[CrossRef](#)]
29. Björklund, C. Less is more—Mathematical manipulatives in early childhood education. *Early Child Dev. Care* **2014**, *184*, 469–485. [[CrossRef](#)]
30. Crollen, V.; Noël, M.-P.; Honoré, N.; Degroote, V.; Collignon, O. Investigating the respective contribution of sensory modalities and spatial disposition in numerical training. *J. Exp. Child Psychol.* **2019**, *187*, 104729. [[CrossRef](#)] [[PubMed](#)]
31. Granone, F.; Reikerås, E. Teachers' support for children's mathematical learning through interactions while playing with a coding toy. *NOMAD Nord. Stud. Math. Educ.* **2023**, *28*, 149–171. [[CrossRef](#)]
32. Granone, F.; Pollarolo, E. Facilitating children's communication in problem-solving activities with a coding toy: Teachers' semiotic mediation in early childhood education and care. *Front. Psychol.* **2025**, *15*, 1426165. [[CrossRef](#)] [[PubMed](#)]
33. Gordon, R.; Ramani, G.B. Integrating embodied cognition and information processing: A combined model of the role of gesture in children's mathematical environments. *Front. Psychol.* **2021**, *12*, 650286. [[CrossRef](#)] [[PubMed](#)]
34. Laski, E.V.; Jor'dan, J.R.; Daoust, C.; Murray, A.K. What makes mathematics manipulatives effective? Lessons from cognitive science and Montessori education. *SAGE Open* **2015**, *5*, 1–8. [[CrossRef](#)]
35. Martinez-Lincoln, A.; Tran, L.M.; Powell, S.R. What the hands tell us about mathematical learning: A synthesis of gesture use in mathematics instruction. *Gesture* **2019**, *17*, 375–416. [[CrossRef](#)]
36. Montoya, M.; Tornero, B.; Farias, D.P.; Morrison, F.J. Linking self-regulation scaffolding to early math achievement: Evidence from Chilean preschools. *Educ. Sci.* **2025**, *15*, 1426. [[CrossRef](#)]
37. Sarama, J.; Clements, D.H.; Wolfe, C.B.; Spitler, M.E. Professional development in early mathematics: Effects of an intervention based on learning trajectories on teachers' practices. *NOMAD Nord. Stud. Math. Educ.* **2016**, *21*, 55–85. [[CrossRef](#)]
38. Thornton, C.; Crim, C.; Hawkins, J. The impact of an ongoing professional development program on prekindergarten teachers' mathematics practices. *J. Early Child. Teach. Educ.* **2009**, *30*, 321–339. [[CrossRef](#)]

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