

DMT INSIGHTS

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THE LASTING IMPACT OF MATH MANIPULATIVES IN EARLY CHILDHOOD EDUCATION

Research on cubes, counters, dice, pattern blocks, and early mathematical development

Introduction

Educators have long used manipulatives to support early childhood mathematical learning. Materials such as connecting cubes, counting chips, dice, wooden blocks, pattern blocks, and cards let children explore quantities, number relationships, spatial structures, measurement, and operations.

Research on early mathematics suggests that carefully selected manipulatives can support mathematical understanding when they are connected to purposeful activities and instruction. With these materials, children can represent quantities, compose and decompose numbers, compare measurements, and investigate shapes and patterns.

Math packs bring these materials together in organized sets for classroom and home use. This DMT Insight examines the evidence supporting manipulatives, the mathematical purposes of different materials, and the role of guided activities in early mathematical development.

Theoretical Foundations

Research on mathematical representations provides a theoretical basis for understanding how manipulatives support learning. Bruner (1966) described enactive, iconic, and symbolic representations, emphasizing different ways learners can express and understand ideas. Physical materials let children act on quantities and relationships, while drawings, mathematical language, and symbols offer additional ways to represent those ideas. Children may use these representations together; they are not a fixed sequence that every child must follow.

Gravemeijer (1999) examined how models can develop from representations of particular situations into tools for mathematical reasoning. This work helps explain how physical materials can become models for mathematical reasoning. For example, a set of cubes can represent a quantity, a unit of measurement, or a mathematical relationship, depending on the task.

The National Research Council (2009) identifies two core areas of early mathematics: number (including relations and operations) and geometry (spatial thinking and measurement). Manipulatives offer opportunities to explore both areas through physical representations that connect to diagrams, language, and symbols.

Key Manipulatives and Their Mathematical Contributions

Early mathematics includes counting, numeration, addition and subtraction, relational thinking, geometry and spatial reasoning, measurement, and patterning (National Research Council, 2009). Different manipulatives have physical characteristics that make them useful for different parts of this mathematics. The table describes the mathematical contributions of common materials. These are mathematical uses of the materials, not claims that each material independently produces measured achievement gains.

Manipulative	Mathematical contributions
Connecting cubes	Counting, composing and decomposing quantities, equal groups, iterating equal units to measure length, spatial structures
Counting chips and counters	One-to-one correspondence, cardinality, comparing quantities, addition and subtraction, part-total relationships
Dice and dot patterns	Subitizing, recognizing quantities, composing numbers, addition and subtraction
Pattern blocks	Shape properties, composing and decomposing shapes, spatial reasoning, patterns, area relationships.
Wooden blocks	Spatial visualization, shape composition, comparing dimensions, informal measurement
Number cards	Number recognition, ordering, comparing magnitude, matching representations, number relationships

The physical characteristics of each material matter. Connecting cubes can be joined into trains of equal-sized units, making them useful for counting, composing and decomposing a quantity, and iterating a unit to measure length. Children can rearrange counting chips to show different decompositions of the same quantity, such as 8 as 5 and 3 or as 4 and 4. Dice present quantities in familiar dot patterns that children can recognize without counting by ones. Pattern blocks let children explore how shapes fit together and how a region, such as a hexagon, can be composed in different ways.

Children may use connecting cubes to compare quantities, dice to recognize and combine numbers, or pattern blocks to compose shapes in different ways. These activities offer opportunities to investigate mathematical relationships when tasks and questions focus on the mathematics the materials represent.

Key Idea • The mathematical characteristics of manipulatives influence the quantities, structures, and relationships children can investigate.

Research Evidence: Impact on Learning and Engagement

Research on concrete manipulatives. Carbonneau et al. (2013) conducted a meta-analysis of 55 studies comparing instruction with concrete manipulatives to instruction with abstract symbols alone, with learners from kindergarten through college. They found small to moderate effects favoring manipulatives, with the largest effects on retention

and smaller effects on problem solving and transfer. The effects depended on instructional and material characteristics, including the level of instructional guidance, the perceptual richness of the materials, and the age of the learners. These findings indicate that manipulatives' effectiveness depends in part on the materials, instructional guidance, and mathematical tasks.

Research on early mathematical development. The National Research Council (2009) concluded that early experiences with number, geometry, spatial thinking, and measurement are important foundations for later mathematics. In a randomized Head Start study, Brendefur et al. (2013) found that four-year-olds whose teachers received professional development and center-based mathematics activities showed stronger number fluency and flexibility, contextual problem solving, and measurement and spatial skills than children in control classrooms. The study examined a professional development program that included center-based mathematical activities and instructional support, rather than the effects of individual manipulatives.

Research on mathematics at home. Anders et al. (2012) followed children from about age 3 to age 5 and found that the quality of the home learning environment was strongly associated with early numeracy skills. Berkowitz et al. (2015) found that first graders whose families used a mathematics app with brief parent-child activities made greater gains in mathematics over the school year, particularly when parents were anxious about mathematics. That intervention was an app, not a set of physical materials. Maloney et al. (2015) found that parents' math anxiety was related to children's lower mathematics learning and higher math anxiety when parents frequently helped with homework. These studies provide evidence about home mathematics experiences and family involvement, although they do not directly evaluate physical math packs.

Key Idea • Research supports the use of manipulatives in mathematics instruction and the importance of guided mathematical activities at home. The studies reviewed here do not establish the relative effectiveness of individual manipulatives.

Implications for Practice: Math Packs at Home and School

Math packs provide families and educators with organized sets of materials that can support early mathematical development. Connecting cubes, counting chips, dice, cards, and pattern blocks can support activities involving counting, comparing, composing and decomposing quantities, spatial reasoning, and measurement.

Research on home mathematics activities suggests that guidance and opportunities for mathematical discussion are important. Families may benefit from materials with clear activity directions and questions that focus on the mathematics children are investigating. Educators can use the same materials in centers, small groups, and family engagement events.

Well-designed math packs bring together materials selected for specific mathematical purposes, along with activities and questions that help children examine the mathematics. Materials should be selected for the mathematical ideas they can represent, and activities should help children recognize and explain those ideas. School-family partnerships can support this work (Epstein, 2018).

Conclusion

Research on concrete manipulatives and early mathematical development supports using carefully selected physical materials in mathematics instruction. Connecting cubes, counting chips, dice, pattern blocks, and other manipulatives give children different opportunities to investigate quantities, operations, measurement, spatial relationships, and mathematical structures.

These materials can support mathematical understanding when children use them in activities that focus on specific mathematical ideas. Organized math packs can extend these opportunities into homes and classrooms by providing manipulatives, activities, and questions that support early mathematical development.

References

- Anders, Y., Roßbach, H.-G., Weinert, S., Ebert, S., Kuger, S., Lehrl, S., & von Maurice, J. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly*, 27(2), 231–244.
- Berkowitz, T., Schaeffer, M. W., Maloney, E. A., Peterson, L., Gregor, C., Levine, S. C., & Beilock, S. L. (2015). Math at home adds up to school achievement. *Science*, 350(6257), 196–198. <https://doi.org/10.1126/science.aac4628>
- Brendefur, J., Strother, S., Thiede, K., Lane, C., & Surges-Prokop, M. J. (2013). A professional development program to improve math skills among preschool children in Head Start. *Early Childhood Education Journal*, 41(3), 187–195. <https://doi.org/10.1007/s10643-012-0543-8>
- Bruner, J. S. (1966). *Toward a theory of instruction*. Harvard University Press.
- Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology*, 105(2), 380–400. <https://doi.org/10.1037/a0031084>
- Epstein, J. L. (2018). *School, family, and community partnerships: Preparing educators and improving schools* (2nd ed.). Routledge.
- Gravemeijer, K. (1999). How emergent models may foster the constitution of formal mathematics. *Mathematical Thinking and Learning*, 1(2), 155–177. https://doi.org/10.1207/s15327833mtl0102_4
- Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science*, 26(9), 1480–1488. <https://doi.org/10.1177/0956797615592630>
- National Research Council. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity*. The National Academies Press. <https://doi.org/10.17226/12519>

Social Media

Connecting cubes, counting chips, dice, and pattern blocks each represent different mathematics: composing and decomposing quantities, comparing, recognizing dot patterns without counting, and composing shapes.

Research supports using manipulatives with a mathematical purpose and guided activities. In DMT Insight 26, we review the research on concrete manipulatives, early mathematical development, and mathematics at home, and what it means for math packs.

Read the full Insight at mathsuccess.io/dmtinsights.

