



## Executive summary

# *Educational interventions involving physical manipulatives for improving children's learning and development: a scoping review*

A PEDAL Report, January 2022

Authors & contributors: Dr. Elizabeth M. Byrne<sup>1\*</sup>; Prof. Paul G. Ramchandani<sup>1</sup>; Kayleigh Skene<sup>1</sup>; Thomas Chupein<sup>2</sup>; Dr. Hanne Jensen<sup>2</sup>; Dr. Celia Hsiao<sup>2</sup>; Dr. Bo Stjerne Thomsen<sup>2</sup>; Dr. Amy Jo Dowd<sup>2</sup>

<sup>1</sup> The Centre for Play in Education, Development, & Learning (PEDAL), Faculty of Education, University of Cambridge, UK

<sup>2</sup> The LEGO Foundation, Billund, Denmark \*Contact: emb72@cam.ac.uk

## Introduction

Physical manipulatives (PMs) are concrete objects that children use during hands-on learning activities. PMs can be useful educational tools as they promote children's active participation in learning and can facilitate playful hands-on experiences. PMs are widely used during math instruction, and there is a growing body of research for their use in other learning domains, often in a play-based context.

## Aim

The current review sought to comprehensively map and synthesise the research literature on educational interventions involving PMs for young children, and to identify gaps in the research.

## Methods

A scoping review methodology was employed. A search strategy was developed to search peer-reviewed literature and unpublished reports (e.g., theses) indexed by electronic databases, covering the period 2000-2020. Following the removal of duplicates, the search yielded 3,112 records, all of which were screened based on their titles and abstracts. Next, full text reports of 918 studies were assessed for eligibility, which ultimately resulted in 102 studies being included in the review. For inclusion, studies must have satisfied various eligibility criteria, including (but not limited to), having a mean sample age between 0-12 years and at least one measurable child outcome. Data were extracted from all included studies and categories were developed to aid synthesis of the available evidence by the type of PMs used in the intervention and/or the learning domain targeted.

## Findings

Studies were largely conducted in high- or upper-middle-income contexts (~97%), primarily in the USA (~59%). Most involved a sample of children with a mean age between 4-6 years (~52%) and took place in a school setting (~78%). The interventions varied greatly in terms of: (a) the PMs that children engaged with, (b) the hands-on activities PMs were used in, (c) the amount of physicality both the PMs and activities afforded children, (d) the degree of adult control and child autonomy (e.g., whether interventions were play-based or didactic), (e) the research methodologies used, and (f) the learning domains targeted (see Figure 1 for a visual summary of these differences).

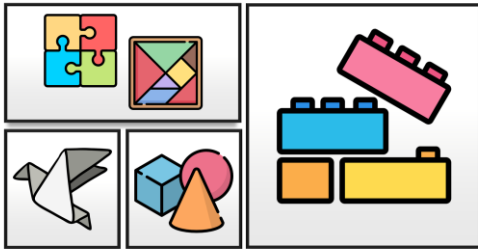
Overall, findings relating to effectiveness were mixed. Some positive effects were reported for children's math and spatial outcomes following interventions involving block building, math-based PMs, puzzles, and paper folding. Benefits were also found to children's vocabulary and literacy skills following reading/literacy-based interventions with PMs. However, there were also numerous reports of null, negative, and inconclusive results, in part due to methodological inconsistencies and shortcomings across studies, meaning that some caution should be exercised when drawing firm conclusions.



## INTERVENTIONS

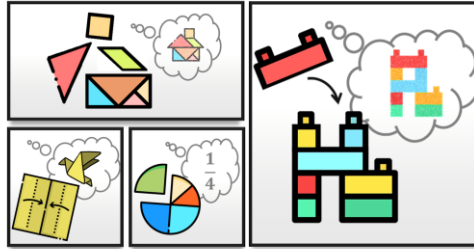
What did children experience in the PM-based programmes?

### MATERIALS



Children engaged with a wide range of physical manipulatives (PMs), such as blocks, bricks, puzzles, math materials like counters & fraction tiles/pies, shapes, paper, & small toys/figurines.

### ACTIVITIES



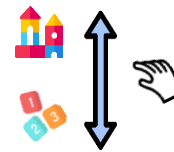
The ways that children used the materials also varied greatly. PMs were used in hands-on activities such as building, counting, origami, making patterns, enacting stories, scientific experimentation, & solving math problems.

### LEVEL OF INSTRUCTION



Some interventions were play-based – affording children freedom & choice within the activities with gentle adult guidance & scaffolding (i.e., guided play), whereas others were highly structured & directed by an adult.

### LEVEL OF PHYSICAL ENGAGEMENT

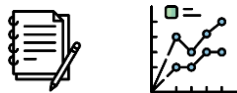


The level of physicality afforded by the materials & activities differed. For example, children taking part in block play & origami interventions engaged in high levels of physical manipulation, whereas activities such as shape sorting or counting with tokens involved lower levels.

## STUDIES

How did studies assess the effectiveness of interventions?

### RESEARCH METHODOLOGIES



Methods used to evaluate interventions varied. Most studies included a comparison group (e.g., intervention compared to business-as-usual, guided play compared to direct instruction/free play, physical versus virtual materials). While some studies had robust research designs, many were limited by methodological issues.

### LEARNING DOMAINS



The PM-based programmes targeted a range of learning domains. Consequently, many different outcome measures were used across the studies, which related to areas such as math & numeracy (e.g., general math ability, fraction knowledge), literacy & language (e.g., expressive & receptive vocabulary, reading), and visual-spatial skills (e.g., mental rotation).

Figure 1. Infographic summarising of some of the broad differences across the reports included in this review, in terms of the interventions delivered to children, and in the way that studies examined these interventions<sup>1</sup>.

<sup>1</sup> The images used in the figure, some of which have been adapted/edited, are attributable to the following designers: *Darius Dan; Freepik; juicy\_fish; Muhammad Ali; photo3idea\_studio; Pixel perfect; & Smalllikeart* (from *Flaticon*).



## Study spotlight

Some examples of interventions with robust research designs that demonstrated particularly promising findings are highlighted in this section, areas for further exploration are also suggested.

### AN INQUIRY-BASED MATH INTERVENTION IN BELIZE

Hull *et al.*, (2018)

Math instruction in Belize typically involves highly prescribed activities (e.g., drill, memorisation), and hands-on learning with physical manipulatives (PMs) is not common practice. In this study, a multifaceted intervention was designed to directly meet the key needs of primary education in Belize, specifically addressing teacher knowledge and school resources. The different components of the intervention included inquiry-based instruction, hands-on activities with cost-effective (homemade) PMs, teacher professional development, and ongoing support for teachers. The programme was well-thought-out and grounded in educational theory. While the programme itself was novel, the authors consolidated existing evidence for the inclusion of each component. After a large-scale year-long trial, the programme was found to enhance children's overall math achievement compared to a control group. The positive results supported a nationwide rollout of the intervention.

An adaptation of this programme may benefit children's math learning in similar contexts, namely low- and middle-income countries where math is usually taught through direct instruction. The study provides evidence that children in a traditionally teacher-centred context respond well to a relatively simple, inexpensive programme that promotes child-centred learning via hands-on activities.

The programme demonstrates good practice for producing stronger and better data, in terms of intervention development (e.g., designed to meet the specific needs of a certain educational context, grounded in existing evidence), and trial design (e.g., robust methodology & analyses). Both contribute to the success of an intervention and its potential impact on real-world policy and practice.



## A PLAYFUL PRE-SCHOOL MATH INTERVENTION IN THE USA

Sophian (2004)

In this study, young preschool children engaged in a playful, curriculum-based math intervention. It was delivered mostly by their teachers, but also involved some at-home activities with parents/caregivers. Like Hull et al., (2018), teachers received training and ongoing support throughout programme delivery.

The curriculum was varied and involved many different PMs, activities, and games. There were different themes each week that focused on different math concepts such as geometry/shapes, measurement, and numbers. Within each theme there were lots of related activities, for example, sorting small toys by size, filling different containers with beans/sand, or using plastic shape tiles to make/fill bigger shapes.

The study had a robust research design and results indicated that the programme benefited children's math ability scores more than control conditions. The results demonstrate how young children's math learning can be supported via teacher-mediated hands-on activities.

Future studies could serve to further test or extend the programme. For example, to examine whether the benefits are replicable in similar contexts, or in novel contexts following adaptation, and to explore whether the programme can be made more cost-effective for potential scaling in lower-resourced settings (e.g., using low-cost materials that teachers could make themselves).

## READ-PLAY-LEARN: AN ENRICHED BOOK-READING INTERVENTION IN THE USA

Toub *et al.*, (2018)

The study aimed to promote pre-school children's language learning through book-reading and play. Children engaged in eight shared book-reading sessions in small groups with an adult researcher. Afterwards, children played with story-relevant materials (e.g., small toys and figurines). Some children received adult support during play: guided play or directed play. In the former, the adult followed the children's lead and incorporated target words at naturally occurring moments. In the latter, the adult used a script with target words and directed children to re-enact the story. Another group of children used the toys however they liked without adult support of vocabulary (free play).

The study was well-designed and produced some promising results: children who received either type of adult support (guided or directed) improved more than those in the free play group on vocabulary measures involving the target words. Additional data from a second study also provided preliminary evidence in support of programme implementation by teachers.

Future work could further explore whether the intervention can be facilitated by teachers instead of researchers. Adaptations of the programme could be piloted to encourage play-based language learning. While PMs are widely used for learning math, they are less common during literacy-based instruction. Research evidence about PM-based literacy interventions is increasing gradually, and further development of programmes in this domain may prove fruitful.



## Key messages & recommendations

---

### **Key message 1 | *Geographical diversity***

Studies were overwhelmingly conducted in high-income countries, with over half taking place in the USA.

#### **Recommendation**

Conduct more research in lower-income countries. Focus on implementing and scaling interventions that have an evidence base, or design interventions with components that have pre-existing evidence. Piloting must precede implementation and scaling if the evidence is mainly derived from high-income countries. Ensure programmes meet context-specific needs and that adaptations are made so they are useful, acceptable, and feasible. Design methodologically rigorous studies to ensure that effective interventions have strong and reliable data to support scaling and potential impact on policy.

---

### **Key message 2 | *Evidence relating to effectiveness & methodological quality***

The literature spanned many different types of interventions and PMs, and the research evidence was mixed. Whilst there were positive findings for some interventions, others showed no effects. Several larger-scale studies with robust designs were identified, but many others were limited by methodological issues, such as small samples, lack of control groups, lack of baseline data, and/or inadequate statistical analyses. Methodological differences between studies mean that overall conclusions on the effectiveness of PMs should be drawn with some caution.

#### **Recommendation**

Recognise that there is a diverse literature for PMs. Conduct high quality and clearly focussed research that will allow stronger conclusions to be drawn in the future. Ensure that future intervention studies have robust research designs (e.g., that have control groups, pre- and post-intervention data - including transfer measures, pre-specified protocols that outline key research questions and methods, and an analysis plan describing how the research questions will be addressed). In addition, a more targeted and systematic examination of the literature may be warranted, as the aggregation of data from the most methodologically robust and large-scale trials may yield firmer conclusions on the overall efficacy of PM-based interventions.

---