

Colorful Box Media as a Cognitive Intervention: Enhancing Three-Seriation Classification Skills in Children Aged 4–5 Years

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Abstract

Purpose	: This study examines the effectiveness of colorful box media as a concrete manipulative intervention to enhance the three-seriation object classification skills of children aged 4–5 years in early childhood education settings.
Methodology	: A Classroom Action Research (CAR) design following Kurt Lewin's cyclical model was employed across two cycles, each comprising planning, implementation, observation, and reflection phases. Sixteen children (7 boys, 9 girls) from Group A of TK PGRI Kabere participated. Data were collected via structured observational checklists aligned with national early childhood development standards (Permendikbud No. 137/2014), covering three classification dimensions: colour, shape, and size. Mastery criteria followed an 80% class completion threshold.
Results	: In Cycle I, 44% of children (n = 7/16) achieved mastery, with persistent difficulties in shape and size classification attributed to ambiguous basket coding and insufficient pre-activity scaffolding. Following targeted modifications in Cycle II, including shape-congruent basket design, competitive game elements, and explicit pre-play orientation, the mastery rate reached 100% (n = 16/16), surpassing the required minimum criterion.
Conclusions	: Colorful box media constitutes an effective, low-cost concrete manipulative for promoting logical classification in young children, provided that material design is developmentally aligned, multi-dimensional in scope, and embedded in structured play-based pedagogical routines. Findings contribute to the evidence base for hands-on media design in early childhood cognitive education.

Keywords: colorful box media, three-seriation classification, classroom action research, early childhood cognitive development, concrete manipulatives

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1. Introduction

Logical thinking constitutes one of the most critical cognitive developmental domains in early childhood education. It forms the foundation upon which higher-order reasoning, problem-solving, and abstract conceptualisation are built across subsequent developmental stages (Clements & Sarama, 2021; Verdine et al., 2017). Among the core indicators of logical thinking in early childhood, the ability to classify objects, particularly through multi-dimensional seriation, holds a prominent position in both developmental theory and national curriculum frameworks (Edens & Potter, 2013). In the Indonesian context, the ability of children aged 4–5 years to classify objects across three seriation dimensions (colour, shape, and size) is explicitly specified as a developmental benchmark within the Kurikulum 2013 PAUD (Permendikbud No. 137/2014), under the cognitive sub-domain of logical thinking.

From a theoretical standpoint, Piaget's preoperational theory emphasises that children between the ages of two and seven years are beginning to develop the capacity for symbolic representation, intuitive reasoning, and early logical operations, including classification and seriation (Ginsburg & Oppen, 2019; Piaget & Inhelder, 1969). Building on this, neo-Piagetian theorists have demonstrated that classification competence, the ability to group objects according to shared attributes, is a prerequisite for mathematical reasoning, early numeracy, and analogical thinking (Alibali & Nathan, 2012; Mazzocco & Thompson, 2005). Classification tasks that require simultaneous attention to multiple object properties (colour, shape, and size) engage visuospatial reasoning and inhibitory control, two executive function components that are highly malleable during the preschool years (Diamond, 2013; Zelazo et al., 2016).

Despite the theoretical significance of classification as a developmental milestone, empirical evidence consistently indicates that many young children exhibit persistent difficulties with multi-attribute classification, particularly when classification criteria involve irregular shapes or ambiguous size gradations (Edens & Potter, 2013; Kidd et al., 2014). These challenges are further compounded by instructional approaches that rely predominantly on passive, teacher-directed methods such as rote questioning or whiteboard-based demonstrations, which fail to provide the embodied, hands-on engagement that supports early cognitive development (Lillard et al., 2013; Weisberg et al., 2016). The absence of concrete manipulatives in such approaches severely limits children's opportunities to physically interact with objects, compare their attributes, and construct classification knowledge through direct sensorimotor experience (Carbonneau et al., 2013).

Previous research has explored various media and instructional strategies for enhancing classification skills in early childhood contexts. Loose parts media, for example, have been shown to facilitate exploratory classification but are primarily suited for open-ended discovery rather than structured multi-dimensional sorting (Daly & Beloglovsky, 2015). Picture-based media have been employed in several studies (Ardiana, 2022) however, their two-dimensional nature limits representational accuracy for shape and size classification, particularly when pictured objects vary in scale across illustrations. Colour-based sorting activities have demonstrated effectiveness for single-attribute classification (Supatmi et al., 2023), yet their scope remains narrow and does not address the multi-dimensional demands of three-seriation tasks. None of these approaches has systematically evaluated a media design that integrates all three classification dimensions, colour, shape, and size, within a single, coherent hands-on learning tool.

There is, therefore, a clear research gap concerning the development and evaluation of concrete manipulative media specifically designed to support simultaneous three-seriation classification learning in preschool children aged 4–5 years. The present study addresses this gap by investigating the effectiveness of colorful box media, a purpose-built three-dimensional sorting system comprising coloured, shape-coded, and size-differentiated baskets and objects, as a classroom intervention implemented through a Classroom Action Research (CAR) design. The study was conducted at TK PGRI Kabere, where pre-intervention data indicated that 50% of Group A children (8 out of 16) had not achieved the expected developmental benchmark for classification.

The research objectives of this study are threefold: (1) to evaluate the extent to which colorful box media can increase the proportion of children achieving classification mastery across two instructional cycles; (2) to identify specific design and pedagogical factors that influence the effectiveness of the intervention; and (3) to contribute empirically grounded insights to the literature on concrete manipulative design in early childhood cognitive education. The novelty of this study lies in the integration of multi-dimensional classification criteria within a single manipulative medium and the systematic analysis of design-instruction interactions through an action research framework.

2. Methodology

2.1 Research Design

This study employed a Classroom Action Research (CAR) design based on the Kurt Lewin cyclical model, which consists of four iterative stages: planning (*perencanaan*), implementation (*pelaksanaan*), observation (*pengamatan*), and reflection (*refleksi*) (Kemmis et al., 2014; McNiff, 2017). CAR was selected as the methodological framework because it aligns with the dual purpose of this study: to improve a specific instructional practice within a real classroom context and to generate systematically documented evidence of change (Mertler, 2019). The cyclical, reflective nature of CAR allows for iterative refinement of the intervention based on empirical evidence collected in each cycle, thereby increasing the pedagogical validity of the findings (Stringer, 2014).

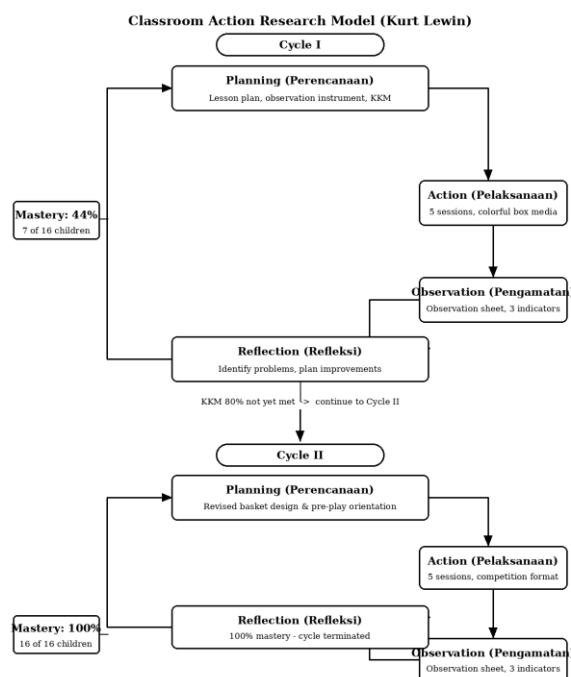


Figure 1. Classroom Action Research model (Kurt Lewin) applied in this study

2.2 Research Setting and Participants

The research was conducted at TK PGRI Kabere, a public kindergarten situated in the Enrekang Regency, South Sulawesi Province, Indonesia. The first author served as the classroom teacher of Group A throughout the intervention, which ensured direct involvement in instructional delivery and naturalistic observation. Participants comprised 16 children enrolled in Group A (aged 4–5 years), consisting of 7 boys and 9 girls. Participants were selected through total sampling given the small class size, which is consistent with CAR conventions (Arikunto et al., 2015). All participants were within the normative developmental range, with no documented special educational needs. Prior to the study, a baseline assessment revealed that 8 of 16 children (50%) had not achieved the expected classification benchmark, indicating a significant and addressable learning need.

2.3 Intervention: Colorful Box Media

The primary intervention instrument was colorful box media, a concrete manipulative system comprising three sets of coloured baskets and associated sorting objects designed to address each classification dimension independently before integration. For colour classification, three baskets were coloured red, blue, and black, paired with colour-matched balls. For shape classification, three basket forms were constructed to be visually and tactilely congruent with target object shapes: a circular basket for balls, a cubic basket for block-shaped objects, and an irregular-form basket for non-standard objects such as natural stones. For size classification, three baskets of distinctly contrasting sizes (small, medium, large) were used alongside objects scaled accordingly. The explicit congruence between basket form and object form was a deliberate design principle intended to reduce cognitive load associated with arbitrary symbolic coding and to leverage the visuospatial matching capacities of preschool-aged children (Carbonneau et al., 2013; Newcombe, 2010).

2.4 Instructional Procedures

Cycle I comprised five instructional sessions. Sessions 1–2 targeted colour classification using the coloured ball-and-basket system, with the teacher modelling the sorting procedure before children engaged in guided and independent practice. Sessions 3–4 focused on shape classification, incorporating tactile object exploration and guided matching activities. Session 5

addressed size classification using paired comparison and group relay activities. Cycle II modifications, informed by Cycle I reflection data, included: (a) replacing all textual basket labels with shape-iconic basket forms to eliminate reliance on literacy competencies; (b) restructuring shape and size activities as individual and group competition formats to increase motivational engagement; and (c) implementing explicit pre-activity orientation sessions (pijakan main) with clear verbal and visual instruction. These modifications were guided by principles of scaffolded instruction and play-based learning theory (Bodrova & Leong, 2015; Weisberg et al., 2016).

2.5 Data Collection and Instruments

Data were collected using a structured observational checklist developed in reference to the Standard for Early Childhood Developmental Achievement (STPPA) specified in Permendikbud No. 137/2014. The checklist comprised three primary indicators: (1) classification by colour, (2) classification by shape, and (3) classification by size. Each indicator was rated on a four-level developmental scale: BB (Belum Berkembang / Not Yet Developed, score 1), MB (Mulai Berkembang / Beginning to Develop, score 2), BSH (Berkembang Sesuai Harapan / Developing as Expected, score 3), and BSB (Berkembang Sangat Baik / Developing Very Well, score 4). The maximum possible score per child was 12 (3 indicators $\times$ 4 points). Instrument validity was established through alignment with national curriculum standards and expert review by two early childhood education specialists, consistent with content validity procedures recommended for action research instruments (Creswell & Poth, 2018).

2.6 Mastery Criteria and Data Analysis

A child was classified as having achieved mastery if their total score met or exceeded 70% of the maximum score ($0.70 \times 12 = 8.4$), yielding a threshold of ≥ 9 points. The class-level mastery criterion for cycle completion was set at 80%, consistent with the minimum completion standard (KKM) established by TK PGRI Kabere. Data analysis involved calculating the proportion of children achieving the mastery threshold in each cycle and comparing pre- and post-cycle descriptive statistics. Qualitative observation notes were also maintained to document contextual factors influencing children's classification performance, providing triangulated evidence for the reflective analyses (Miles et al., 2014).

3. Results

3.1 Cycle I Outcomes

Following five instructional sessions in Cycle I, observational data indicated that 7 of 16 children (43.75%) achieved the mastery threshold (total score ≥ 9). The nine children who did not achieve mastery recorded scores predominantly in the MB range (scores 5–7), with one child falling within the BB range (score 5). Individual score distributions are reported in Table 1.

Table 1. Children's Classification Performance in Cycle I (N = 16)

No.	Child ID	Score	Category	No.	Child ID	Score	Category
1	WW	7	MB (Not Mastered)	9	JKF	12	BSB (Mastered)
2	DSF	8	BSH (Mastered)	10	JHDSB	7	MB (Not Mastered)
3	POWR	7	MB (Not Mastered)	11	OSIEF	7	MB (Not Mastered)
4	JDF	9	BSB (Mastered)	12	UI	6	MB (Not Mastered)
5	IUE	10	BSB (Mastered)	13	UIEF	9	BSH (Mastered)
6	SIUDF	6	MB (Not Mastered)	14	JDSF	9	BSH (Mastered)
7	NFJK	5	BB (Not Mastered)	15	JTSF	7	MB (Not Mastered)
8	UIHEHF	8	BSH (Mastered)	16	BDBF	7	MB (Not Mastered)

Note. BB = Belum Berkembang; MB = Mulai Berkembang; BSH = Berkembang Sesuai Harapan; BSB = Berkembang Sangat Baik. Mastery threshold = total score ≥ 9 (70% of maximum 12 points). KKM (class mastery) = 80% of children achieving threshold.

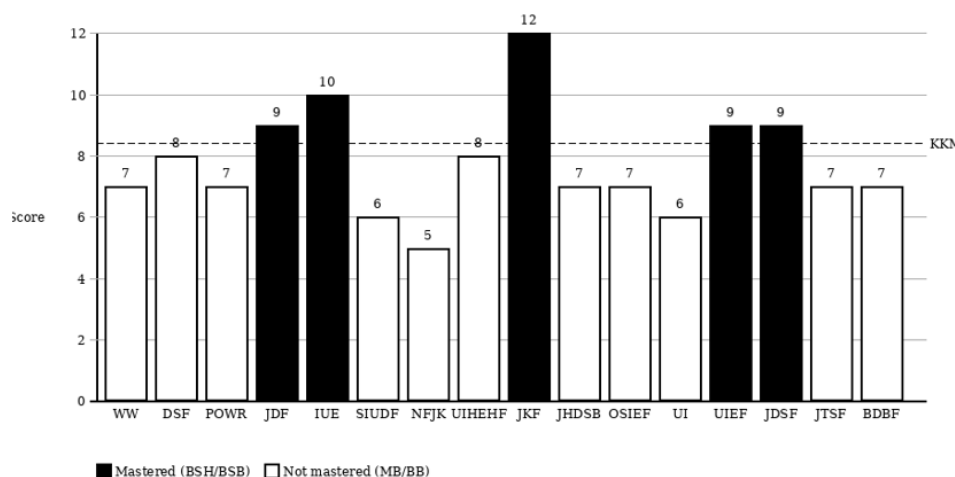


Figure 2. Individual classification scores of children in Cycle I.

Observational data from Cycle I indicated that colour classification was the dimension most successfully acquired, with the majority of children able to match colour-coded balls to the corresponding basket. Persistent difficulties were observed in shape and size classification. In shape classification, children with scores in the MB range showed difficulty categorising irregular-shaped objects, likely due to the absence of visually distinctive basket forms that communicated the sorting criterion non-verbally. In size classification, comparative size judgements across small, medium, and large categories were inconsistent, particularly for medium-category objects which lacked clear perceptual anchors. These findings informed the targeted design modifications implemented in Cycle II.

3.2 Cycle II Outcomes

Following the design and instructional modifications described in Section 2.4, Cycle II was implemented across five sessions. The results demonstrated a marked improvement in classification performance. All 16 children (100%) achieved the mastery threshold, with 13 of 16 children scoring in the BSB range (total score ≥ 10) and 3 children scoring in the BSH range (total score 9). Individual Cycle II scores are reported in Table 2.

Table 2. Children's Classification Performance in Cycle II (N = 16)

No.	Child ID	Score	Category	No.	Child ID	Score	Category
1	WW	11	BSB (Mastered)	9	JKF	12	BSB (Mastered)
2	DSF	12	BSB (Mastered)	10	JHDSB	9	BSH (Mastered)
3	POWR	9	BSH (Mastered)	11	OSIEF	10	BSB (Mastered)
4	JDF	12	BSB (Mastered)	12	UI	9	BSH (Mastered)
5	IUE	11	BSB (Mastered)	13	UIEF	12	BSB (Mastered)
6	SIUDF	9	BSH (Mastered)	14	JDSF	11	BSB (Mastered)
7	NFJK	10	BSB (Mastered)	15	JTSF	12	BSB (Mastered)
8	UIHEHF	11	BSB (Mastered)	16	BDBF	11	BSB (Mastered)

Note. All 16 children achieved the mastery threshold (score ≥ 9) in Cycle II. Mean score: $M = 10.75$, $SD = 1.06$.

As presented in Table 2, the Cycle II intervention produced a substantial and uniform improvement across all 16 participants, with every child achieving or surpassing the mastery threshold of 9 points. The majority of children ($n = 13$, 81.25%) attained the highest developmental category (BSB, score ≥ 10), while the remaining three children (18.75%) achieved the BSH level (score = 9), indicating solid mastery. The mean score increased markedly from 7.69 (Cycle I) to 10.75 (Cycle II), with a notably reduced standard deviation ($SD = 1.06$), reflecting greater consistency in performance across the class. The elimination of textual basket labels in favour of shape-congruent basket forms, combined with the introduction of structured competitive game formats and explicit pre-activity orientation, appears to have substantially reduced the perceptual and cognitive barriers that impeded classification accuracy in

Cycle I. Particularly notable is the performance of children who previously fell in the MB or BB range (e.g., WW: 7 → 11; NFJK: 5 → 10; SIUDF: 6 → 9), suggesting that the revised instructional design was especially effective for lower-achieving learners. These findings indicate that the class-level KKM criterion of 80% mastery was not only met but exceeded, with 100% of children achieving the benchmark, thereby satisfying the criteria for cycle termination.

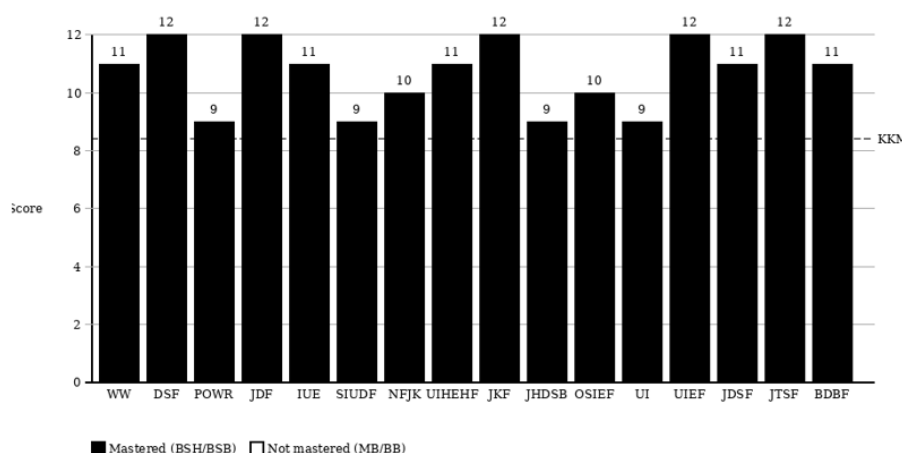


Figure 3. Individual classification scores of children in Cycle II.

Figure 3 further illustrates the uniformity of achievement in Cycle II: all 16 bars reach or exceed the KKM dashed threshold line, in stark contrast to the mixed pattern observed in Figure 1 where nine bars fell below the criterion. The visual distribution confirms that improvements were not confined to children who were near the threshold in Cycle I; rather, gains were distributed across the full performance range. Children in the lowest-scoring group in Cycle I NFJK (score 5, BB) and SIUDF (score 6, MB) both achieved BSB-level scores in Cycle II (10 and 9, respectively), demonstrating that the revised media design and instructional scaffolding were effective even for children with the weakest initial classification competence. The narrow spread of scores in Cycle II (range: 9–12; SD = 1.06) further suggests that the colorful box media intervention, when implemented with shape-congruent materials and structured play-based orientation, functioned as an equalising instructional tool, elevating the performance floor of the class while maintaining high-end achievement.

3.3 Comparative Summary

Table 3 summarises the comparative achievement rates across the two instructional cycles, demonstrating an increase from 43.75% mastery (Cycle I) to 100% mastery (Cycle II), representing a gain of 56.25 percentage points.

Table 3. Comparative Classification Mastery Rate Across Cycles

Indicator	Cycle I	Cycle II
Children Mastered (n)	7	16
Total Children (N)	16	16
Mastery Rate (%)	43.75%	100%
KKM Threshold Met?	No (< 80%)	Yes (= 100%)

Note. KKM = Kriteria Ketuntasan Minimal (Minimum Completion Criterion), set at 80% for TK PGRI Kabere.

4. Discussion

The results of this study demonstrate that colorful box media, when designed and implemented in accordance with developmentally appropriate principles, constitutes an effective concrete manipulative for promoting three-seriation classification skills in children aged 4–5 years. The progression from a 43.75% mastery rate in Cycle I to 100% in Cycle II is consistent with the broader literature on the efficacy of hands-on, object-based learning in early childhood cognitive education (Carbonneau et al., 2013; Uttal et al., 2013).

The comparative difficulty of colour versus shape and size classification observed in Cycle I aligns with existing evidence regarding the perceptual salience of colour as a classification cue in young children. Colour provides the most immediate and global perceptual signal for object grouping, whereas shape and size classification require more fine-grained perceptual differentiation and, in the case of size, the capacity for transitive comparison (Edens & Potter, 2013; Kidd et al., 2014). Research by Libertus and Brannon (2009) has demonstrated that numerical and size discrimination abilities in preschoolers are significantly influenced by the perceptual distinctiveness of the stimuli, which directly supports the observed difficulties with the size dimension in the current study.

The failure of textual labels to serve as effective basket-identification cues in Cycle I reflects a well-documented limitation of text-based scaffolding with pre-literate learners. Young children aged 4–5 years are in the emergent literacy phase and cannot reliably decode written words as category anchors (Whitehurst & Lonigan, 1998). The substitution of shape-iconic basket forms in Cycle II operationalised the principle of symbolic congruence, whereby the representational medium shares structural properties with the referent, which has been shown to significantly reduce cognitive load and improve children's encoding of category boundaries (DeLoache, 2004; Marzolf & DeLoache, 1994). This finding is also consistent with Safita & Suryana (2022) demonstration that symbolic, non-textual markers (e.g., colour sticks) effectively communicate classification categories to pre-literate children.

The significant improvement achieved through the introduction of competition-based game formats in Cycle II is theoretically grounded in motivational and self-determination theory (Deci & Ryan, 2000; Ryan & Deci, 2017). The competitive relay and individual challenge activities increased children's intrinsic engagement by providing immediate, visible feedback on performance and by creating a social comparison context that is naturally motivating for children in this developmental stage (Bodrova & Leong, 2015). Weisberg et al. (2016) have similarly argued that play-based learning structures enhance the transfer of cognitive skills by embedding skill practice within contexts of high affective engagement. The present findings provide empirical support for this theoretical position within the specific domain of classification learning.

The role of explicit pre-activity orientation (pijakan main) as a mediating factor in Cycle II outcomes warrants theoretical attention. Pre-activity scaffolding, which establishes shared understanding of task goals, rules, and procedural expectations prior to independent practice, has been theorised within Vygotskian frameworks as a mechanism for expanding the zone of proximal development (Bodrova & Leong, 2015; Vygotsky, 1978). By ensuring that all children understood the classification criteria before engaging with the materials, the teacher reduced the cognitive burden associated with simultaneous task understanding and task execution, allowing working memory resources to be directed toward classification reasoning per se (Diamond, 2013).

The study's findings also carry practical implications for media design in early childhood classrooms. The principle of material-category congruence, designing sorting containers to be physically isomorphic with target object categories, represents a design heuristic that is both theoretically justified and practically implementable with low-cost, locally available materials. This is particularly relevant for educational contexts in developing countries, including Indonesia, where access to commercially produced instructional media is often limited (Suryadarma & Jones, 2013). The colorful box media in this study was constructed from accessible materials, suggesting strong potential for replication and adaptation in comparable settings.

Regarding limitations, the study's sample size ($N = 16$) and single-site design constrain the generalisability of the findings. CAR studies are, by design, context-specific and intended to generate locally valid knowledge rather than universally transferable conclusions (McNiff, 2017; Mertler, 2019). Furthermore, the absence of a control group means that the observed improvement cannot be attributed exclusively to the media intervention, as maturation, teacher effects, and test familiarity may also have contributed to the Cycle II gains. Future research should employ quasi-experimental or randomised controlled designs with larger and

more diverse samples to provide stronger causal evidence for the effectiveness of colorful box media. Longitudinal follow-up studies would also be valuable to examine whether classification competencies developed through this intervention are maintained and transferred to novel contexts over time.

5. Conclusion

This Classroom Action Research study investigated the effectiveness of colorful box media in enhancing the three-seriation object classification skills of children aged 4–5 years at TK PGRI Kabere. The findings demonstrate a substantial increase in class mastery from 43.75% (Cycle I) to 100% (Cycle II), fulfilling and exceeding the minimum completion criterion of 80%. The progressive improvement was attributable to a combination of targeted material redesign, specifically the adoption of shape-congruent basket forms and tactilely distinct size categories, and refined instructional strategies including explicit pre-activity orientation and competitive game formats.

These findings confirm that colorful box media constitutes a viable, low-cost, and pedagogically sound concrete manipulative for supporting three-dimensional classification learning in preschool settings. The study contributes three specific insights to the early childhood education literature: (1) the principle of material-category congruence as a design guideline for classification media; (2) the importance of pre-activity scaffolding as a pedagogical prerequisite for hands-on classification tasks; and (3) the role of game-based motivational structures in sustaining children's engagement with cognitively demanding classification activities.

Future research should extend this work through quasi-experimental designs involving larger samples, control group comparisons, and longitudinal assessments of classification skill retention and transfer. Cross-context replications in diverse early childhood education settings, including urban, rural, and resource-constrained environments, would further establish the generalisability and adaptability of colorful box media as a cognitive learning tool.

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